

**Development and evaluation of a smartphone app to
reduce excessive alcohol consumption:
Self-regulatory factors**

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Declaration

I, David Crane, confirm that the work presented in this thesis is my own. Where information has been derived from other sources I confirm that this has been indicated in the thesis.

The following work was carried out at the Department of Clinical, Educational and Health Psychology, University College London, under the supervision of Prof Susan Michie, Dr Jamie Brown and Prof Robert West. This thesis has not been submitted, in whole or in part, for any other degree, diploma or qualification at any other University.

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A handwritten signature in black ink, appearing to read 'David Crane', with a large, stylized initial 'D'.

Signature

London, 28 April 2017

Abstract

Alcohol consumption is a major public health issue. Alcohol is responsible for millions of deaths each year, is a causal factor in over 200 diseases and conditions and is a leading contributor to the global burden of disease. Brief interventions to reduce alcohol consumption have demonstrated a record of effectiveness, whether delivered face-to-face or digitally. Most digital behaviour change interventions (DBCIs) for alcohol reduction have been performed on a computer. Smartphone apps are a new and, due to their widespread adoption and rich technological capacities, potentially very useful modality for delivering DBCIs. However, there is currently little evidence of the effectiveness of health behaviour change apps in general and alcohol reduction apps in particular.

This thesis describes the development and evaluation of an app to help people reduce their consumption of alcohol. The aim is to identify which behaviour change techniques (BCTs) may be most effective in helping people reduce their alcohol consumption when delivered in this modality. In a series of three studies, BCTs have been selected for evaluation and their implementation refined. The first study examined the BCTs used in existing popular alcohol-reduction apps; the second undertook a meta-regression of the effectiveness of BCTs used in DBCIs; the third determined how the implementation of the BCTs selected for evaluation could be improved in response to user feedback. Accompanying work reviewed the literature for potentially effective BCTs for alcohol reduction. In the fourth and final study, the BCTs chosen for inclusion in the app were placed into a series of five modules: self-monitoring and feedback, action planning, normative feedback, identity change and cognitive bias retraining, and were evaluated in a factorial randomised control trial (RCT).

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Oral presentations

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Summary

Chapter 1: Introduction

Alcohol consumption is a major public health issue. Alcohol is responsible for millions of deaths each year, is a causal factor in over 200 diseases and conditions and is a leading contributor to the global burden of disease [1–3]. Brief interventions to reduce alcohol consumption have an established record of effectiveness, whether delivered face-to-face or digitally [4–7]. Most digital behaviour change interventions (DBCIs) for alcohol reduction have been performed on a computer.

Smartphone apps are a new and, due to their widespread adoption and rich technological capacities, a potentially very useful modality for delivering DBCIs. However, there is currently little evidence of the effectiveness of health behaviour change apps in general and alcohol reduction apps in particular.

This thesis describes the development and evaluation of an app to help people reduce their consumption of alcohol. The aim is to identify which behaviour change techniques (BCTs) may be most effective in helping people reduce their consumption when delivered in this modality. BCTs have been selected for evaluation and their implementation refined in a series of three studies. The first examined the BCTs used in existing popular alcohol-reduction apps; the second undertook a meta-regression of the effectiveness of BCTs used in DBCIs; the third determined how the implementation of the BCTs selected for evaluation could be improved in response to user feedback. Accompanying work reviewed the literature for potentially effective BCTs for alcohol reduction. In the fourth and final study, the BCTs chosen were placed into a series of modules within an app for evaluation in a factorial randomised controlled trial (RCT). The results relating to the self-regulatory factors of self-monitoring and feedback and action planning are the focus of this thesis.

Chapter 2: Behaviour change techniques in popular alcohol reduction apps:

Content analysis

Few evaluations of alcohol apps have been undertaken. In the absence of effectiveness trials, one approach for identifying BCTs to include in a new app is to perform a content analysis of the BCTs contained in existing apps. Hundreds of alcohol-related apps are available but little systematic information about their content has been gathered. The objective of this chapter is to assess the proportion of popular alcohol-related apps in the UK that focus on alcohol reduction, identify the BCTs they contain, determine the extent to which alcohol reduction apps use BCTs commonly found in other types of behaviour change intervention and assess whether the inclusion of BCTs, or the mention of theory or evidence, is associated with app popularity or user ratings.

The Apple App Store and Google Play Store were searched for the terms 'alcohol' and 'drink'. The first 800 results were classified into one of four categories: alcohol reduction, blood alcohol content measurement, entertainment, or other. Sixty-one alcohol reduction apps (all of the 51 free apps and 10 paid-for apps) were coded for BCTs and for reference to scientific evidence or theory.

Associations between BCTs and the popularity and user ratings of these apps were examined with linear regression models.

Of the 662 unique apps identified, only 13.7% were classified as alcohol reduction. The 61 alcohol reduction apps contained a mean of 3.6 BCTs (SD: 3.4). Evidence was mentioned by 16.4% of apps; theory was not mentioned by any. These apps tended not to include the 22 BCTs frequently used in other health behaviour change interventions (mean: 2.46, SD: 2.06). Multivariable regression models showed that apps including advice on environmental restructuring were associated with lower user ratings ($B = -46.61$; $p = 0.04$; 95% CI: 91.77 to -1.45). The BCT 'Facilitate the use of social support', ($B = 2549.21$; $p = 0.04$; 95% CI: 96.75 to 5001.67) and the mention of evidence ($B = 1376.74$; $p = 0.02$; 95% CI: 208.62 to 2544.86) were associated with the popularity of the app.

Findings that only a minority of apps promote drinking reduction, that an alcohol reduction app's popularity is associated with its mention of evidence, but that these apps tend not to use BCTs commonly found in other interventions, suggests the need for an app which uses BCTs with evidence of effectiveness.

A taxonomy of 93 different BCTs has been developed by consensus methods with input from a large group of international behaviour change experts [8]. Investigating the BCTs used in formally evaluated alcohol reduction DBCIs, and examining their association with intervention effectiveness, may help determine which of these 93 BCTs might be most effective in an app.

Chapter 3: Behaviour change techniques used in digital behaviour change interventions to reduce excessive alcohol consumption: A meta-regression

A large number of DBCIs to reduce alcohol consumption have been developed and evaluated, however little is known about their mechanisms of action. Behaviour change interventions are often complex and consist of a number of BCTs [9]. It is important, therefore, not just to consider individual BCTs but to examine the potential effectiveness of combinations of BCTs. To understand which BCT combinations are likely to be effective we need to turn to theory. Theories provide an analytical framework through which understanding may be gained of how and why an intervention was effective [10,11]. Control Theory, which states that behaviour is goal-driven and that feedback about a discrepancy between current behaviour and a goal leads to behavioural adjustments [12], is a promising theory for health behaviour change interventions. Systematic reviews have found that interventions including more than one of the techniques in Control Theory have resulted in greater amounts of behaviour change than interventions which only included one technique [13,14].

The objective of this chapter was to describe the BCTs used in alcohol reduction DBCIs; identify whether individual BCTs are associated with intervention effectiveness and examine whether the

inclusion of more BCTs or more Control Theory congruent BCTs is associated with increased effectiveness.

Forty-one randomised control trials included in a Cochrane review of alcohol reduction DBCIs were coded for BCTs using an established and reliable method (BCTTv1. [8]). A series of random effects univariable and multivariable meta-regression models were performed to assess associations between BCTs and the effect size of the intervention.

Interventions used a mean of 9.1 BCTs (SD: 5.3). The BCTs of 'Behaviour substitution' (B_{adj} : -101.70; $p < 0.01$; 95% CI: -172.61 to -30.79) and 'Credible source' (B_{adj} : -31.19; $p = 0.04$; 95% CI: -60.70 to -1.69) were significantly associated with reduced alcohol consumption. 'Feedback' was used in 95% of trials ($n = 39$); other Control Theory congruent BCTs were used less frequently: 'Action planning' was used in 32% of trials ($n = 23$), 'Goal setting' in 30% ($n = 12$) and 'Self-monitoring' in 27%, ($n = 11$). The inclusion of more BCTs, or more Control Theory congruent BCTs, was not significantly associated with intervention effectiveness.

Two BCTs, 'Behaviour substitution' and 'Credible source', were associated with the effectiveness of alcohol reduction DBCIs. BCTs such as 'self-monitoring', 'feedback', 'action planning' and 'goal setting', were not frequently used. As these BCTs have evidence of effectiveness in other health behaviour change domains, further examination of their suitability for use in an alcohol reduction app is warranted.

Chapter 4: Selection of the modules

This chapter synthesises findings from previous chapters, and evidence and theory from the scientific literature, to describe the selection of BCTs to be included in the app and evaluated for effectiveness.

A substantial body of theory and evidence exists for the effectiveness of the BCTs of self-monitoring, feedback, action planning and goal setting. They are recommended in NICE guidance for behaviour change interventions [15] and were the four most important BCTs that a group of alcohol and behaviour change experts thought likely to be effective in an alcohol reduction app [16]. This chapter details how the BCTs have previously been implemented in digital interventions and specifies how they will be implemented in the new app.

All BCTs to be evaluated were placed into modules and the modules were specified in two conditions: an 'enhanced' condition containing enhanced elements of the module for the experimental group and a 'minimal' condition for the control group. A commercial app development company was selected to build the app and a first version was launched in May 2015 in the UK version of the Apple App Store.

Chapter 5: Exploring user views toward a smartphone app to reduce excessive alcohol consumption: A usability study

Understanding the ways in which users engage with technology is an essential part of digital intervention development [17]. Two usability studies were conducted in order to gain a detailed understanding of the usability of the app in terms of the extent and manner of user engagement with the modules; the features of the app that users liked and disliked; the degree to which they found the app easy or difficult to use; and how far the app met their needs. The two usability studies were a think aloud study during users' first exposure to the app and a semi-structured interview study with experienced users. Each study involved 12 participants who reported wanting to reduce their consumption of alcohol. Half the participants had no post-16 educational qualifications or were unemployed or employed in a routine/manual occupation.

Three main themes were identified in the data: 'Feeling lost and unsure of what to do next'; 'Make the app easy to use'; and 'Make the app beneficial and rewarding to use'. These themes reflected participants' need for: 1) guidance, particularly when first using the app or when entering data; 2) the data entry process to be simple and the navigation intuitive; 3) neither the amount of text nor range of options to be overwhelming; 4) the app to reward them for effort and progress; and 5) it to be clear how the app could help their alcohol reduction goals be reached. Changes arising from the usability study were implemented into the app and the updated version was evaluated in a factorial randomised control trial (RCT).

Chapter 6: Evaluating the effectiveness of a smartphone app to reduce excessive alcohol consumption: A factorial randomised control trial

A between-group factorial RCT evaluated the effectiveness of the modules chosen for inclusion in the app: Self-monitoring and Feedback; and Action Planning in this thesis. Normative Feedback; Cognitive Bias Re-training; and Identity Change in a related thesis [18]. Participants received either an 'enhanced' or a 'minimal' version of each module and were followed-up one month after downloading the app. The primary outcome measure was change in past week consumption of alcohol, with analysis based on intent-to-treat. Secondary outcome measures were change in AUDIT score, app usage data and app usability ratings.

A total of 672 participants were randomised. At baseline, the mean number of units consumed in the past week was 40 and the mean AUDIT score was 19. There was an overall mean reduction in consumption of alcohol and AUDIT score at follow-up. There were no significant differences in the change in past week consumption or AUDIT score between participants receiving the enhanced and minimal versions of any modules. There was a significant interaction between the Self-Monitoring and Feedback and Action Planning modules, such that a lower AUDIT score resulted when both modules were in their enhanced condition; when either or both modules were in a minimal

condition no significant effect on AUDIT score was detected. Participants given the enhanced version of the Self-monitoring and Feedback module used the app significantly more often, rated it more helpful and more satisfying, and were more likely to recommend the app to a friend, than participants given the minimal version.

The finding that enhanced Self-monitoring and Feedback increased measures of app usability and the finding of an interaction between enhanced Self-monitoring and Feedback and enhanced Action Planning on a reduced AUDIT score at follow-up, indicates that both modules should be considered for evaluation against a minimally active control in their enhanced conditions in a future RCT.

Chapter 7: General discussion

This chapter summarises the work undertaken for this thesis, its strengths and limitations are highlighted, potential implications of the findings are discussed and avenues for further research are suggested.

1 Introduction: The problem of excessive alcohol consumption

Alcohol consumption is responsible for approximately 3.3 million deaths and 139 million disability-adjusted life years each year worldwide [1]. It is a causal factor in over 200 diseases and conditions, including cancers of the mouth, larynx, liver and breast; cardiovascular diseases and immunological disorders; lung, skeleton and muscular diseases; gastrointestinal conditions; reproductive disorders and prenatal harm [2,19]. In addition to its harmful effects on organs and tissues, alcohol intoxication impairs physical coordination, consciousness, cognition and perception [1]. Its consumption can lead to mental and behavioural disorders, numerous social and interpersonal problems, and can increase risky behaviour which can result in injury to the self or others [20,21].

Alcohol-related harm is determined not just by the volume of alcohol consumed but also by patterns of drinking, with individual bouts of heavy drinking associated with detrimental outcomes [22,23]. Young people are more vulnerable to harms from alcohol and tend to engage in more heavy drinking episodes, whereas older people experience alcohol-related health problems on a more frequent basis [1,24–26]. Alcohol is the third-leading contributor to the global burden of disease for men, behind only smoking and high blood pressure [3]. Fewer women drink than men and they tend to drink less frequently and in lower amounts; nonetheless, women may be more vulnerable to alcohol-related harm from given patterns or levels of drinking [1]. People in higher socio-economic groups tend to drink more than people in lower socio-economic groups, but people in lower socio-economic groups consistently experience more alcohol-related problems [27,28].

Excessive alcohol consumption is particularly prevalent in the UK. Average alcohol consumption in OECD countries decreased by an average of 9% over the past 30 years but consumption in the UK increased by 9% in the same period [29]. A quarter of all adults in England are reported to consume

alcohol at hazardous levels [30], defined as a score of 8 or more on the Alcohol Use Disorders Identification Test (AUDIT) [31]. This figure is likely to underrepresent problem drinkers, many of whom may be unwilling to disclose the exact nature of their consumption, and homeless people, a disproportionate number of whom drink at dependent levels [30].

Guidelines for consumption in the UK have recently been revised downwards, with both men and women advised to consume no more than 14 units of alcohol per week [32]; an amount that more than two million people in the UK frequently drink in excess of in a single day [33]. Even using previous guidelines of no more than three to four units per day for men and two to three units per day for women, over 10m people regularly drink in excess of the government's recommended daily limit [34] and 2.6m drink more than twice the limit [35]. These drinkers account for 75% of all alcohol consumed in the UK [35].

Alcohol is the third biggest risk factor for death and disease in the UK, only smoking and obesity contribute more [36]. There were 8,697 alcohol-related deaths in the UK in 2014, a decrease from the peak in 2008 but an increase from 1994, when records began [37]. Drink-driving accounted for 16% of all road deaths and 1,200 serious injuries in the UK in 2012 [38]. Alcohol-related disease, injuries or conditions were responsible for an estimated 1.2 million hospital admissions in England in the year 2011/12, more than double the number from 2002/03 [39]. Approximately ten million violent crimes were committed between 2001 and 2010 in England and Wales where the victim believed the offender(s) to be under the influence of alcohol [40].

Public Health England calculated that alcohol consumption cost the UK £47 billion in 2016 [41]. Costs to the healthcare, welfare, police and criminal justice systems were estimated at £13 billion, and costs from lost productivity at £34 billion. This figure does not take into account the intangible costs of alcohol-related pain and suffering.

The most recent figure for the cost of consumption is more than double the previously reported figure of £21 billion [42] and reflects an update of previous years' estimates to their equivalent costs in 2016, as well as a different methodological approach. The previous figure was calculated on the basis that alcohol consumption cost the equivalent of 1.3% of gross domestic product (GDP) [41], whereas the new figure used a population-weighted average of the costs of consumption reported in four studies of high income countries [2] to estimate that alcohol consumption cost the equivalent of 2.5% of GDP. However, the population-weighted average may have been skewed by a study in the United States, which estimated that alcohol cost their economy the equivalent of 2.7% of GDP. Another of the four studies estimated the costs of alcohol in Scotland to amount to 1.4% of GDP [43]. Scotland consumes a broadly similar amount of alcohol to the rest of the UK [44]. Therefore, it may be more accurate to estimate the cost of alcohol consumption as between 1.4% and 2.5% of GDP, or £26 to £47 billion for the UK in 2016.

In summary, the economic, health and societal costs of alcohol mean that tackling excessive consumption is a public health priority [45,46] and there is a clear need for interventions to help people reduce their consumption.

1.1 Individual differences in alcohol consumption

1.1.1 Expectancies

Individual differences in alcohol consumption can result from the positive and negative outcomes expected from drinking. The positive expectancies most commonly reported are that alcohol will enhance mood, reduce tension, increase social, sexual and physical pleasure, and boost feelings of power, aggression and social assertiveness [47]. Negative expectancies are that alcohol will affect performance and self-control, increase the likelihood of injuries and aggression and create unpleasant physical sensations when consumed in large amounts [48,49]. Negative expectancies are

associated with reduced consumption [50]. Positive expectancies are associated with increased consumption [50] and more strongly predict consumption [51]. Coping expectancies, those held about alcohol's ability to help people avoid, escape from or otherwise regulate negative affect, are particularly associated with excessive consumption [52,53]. Heavier drinkers tend to hold more positive and fewer negative expectancies than lighter drinkers [54], and the strength and accessibility of positive expectancies has been associated with heavier drinking and more alcohol related problems [55].

Attempts to manipulate expectancies experimentally have been met with limited success. A review of expectancy manipulations found that increasing positive or negative expectancies respectively increased or decreased consumption, but as changes were measured shortly after experimental manipulation it is unclear whether effects would remain over time; other studies with longer follow-up periods reduced positive expectancies but did not affect consumption [50]. Social Learning Theory [56] may explain why expectancies are difficult to manipulate; the theory, when applied to alcohol, posits that expectancies are formed from the way drinking is modelled by family members, peers and people in the media, and are reinforced with age and drinking experience [57]. Repeated experience with alcohol and its effects strengthens associations with positive or negative expectancies and may reduce the influence of information that contradicts those expectancies [58].

1.1.2 Alcohol-related cues

As expectancies are reinforced they can become associated with, and recalled by, alcohol-related cues such as alcoholic drinks or the environment in which they are consumed. For example, heavy drinkers sat in a bar (but who had not consumed alcohol) had greater expectations about increased stimulation and pleasurable disinhibition from alcohol than heavy drinkers who answered the same questions in a laboratory [59]. When alcohol-related cues are associated with alcohol's positive effects subsequently encountering these cues can result in increased expectancies about alcohol's

availability, greater attentional bias toward alcohol cues and increased cravings to drink [60].

Interacting with an alcoholic beverage (opening a beer, pouring it into a glass, holding and smelling it, imagining drinking it and evaluating its desirability) resulted in greater attentional bias towards alcohol distractor words in a Stroop task in heavy drinking participants, but not in heavy drinkers who did not interact with the beverage or in light drinkers in either condition [61]. Heavy drinkers situated in a room with alcohol-related imagery exhibited slower reaction times on a Stroop task with alcohol distractor words than either heavy drinkers situated in a room with control imagery or light drinkers exposed to either types of imagery [62].

Attentional bias and cravings are considered to have reciprocal excitatory effects on each other, i.e. increases in the salience of alcohol-related cues can result in increased cravings and vice-versa, increases in cravings can result in increased salience of alcohol-related cues [60]. Cravings have been induced by exposing subjects to alcoholic beverages or their visual representations, manipulating mood states and controlling environmental settings (for a review see [63]). However, when participants are asked to look at, hold and smell a beverage, cravings are typically increased in no more than 60% of subjects; more robust craving increases are found when participants repeat the drinking practices they are accustomed to, i.e. by choosing or mixing their own drink and pouring it into a glass [63].

Alcohol also has a 'priming effect'; participants primed with a low amount of ethanol consistently display more cravings for alcohol than participants primed with a placebo; and the effect on subsequent consumption appears to be dose-dependent on the amount of ethanol given at baseline (e.g. [64–66]). Priming doses may increase the desire to drink by making instigating cues more salient and making inhibiting cues less so [48,67]. Priming doses may also facilitate the easy recall of positive past experiences with the drug, which increases an individual's motivation to consume more alcohol in order their positive expectancies be realised [68].

1.1.3 Self-regulation

Attempts to self-regulate drinking behaviour are impeded by reinforced expectations about alcohol's effects, alcohol-related cues, and priming doses of alcohol; all of which have a motivational effect on consumption that lies outside full conscious awareness and self-regulatory control. Self-regulation to reduce consumption is also impeded once even moderate doses of alcohol have been consumed [69]; alcohol makes effortful cognitive processing more difficult, decreases self-standards of conduct, narrows attentional focus, decreases the ability to inhibit responses and impairs executive functioning (see [48] for a review). Alcohol consumption has been associated with a range of poor self-regulatory skills such as low self-control [70], high susceptibility to temptation [71], low self-efficacy to control drinking [72], difficulty delaying gratification [73] and poor response inhibition [74]. Alcohol consumption can result in 'alcohol myopia': a single-minded focus on an individual's immediate environment, a reduction in the ability to evaluate the consequences of their actions and reduced sensitivity to appropriate standards of conduct [75,76]. Participants given a low dose of alcohol reported greater intentions to engage in risky sexual behaviour than controls not given alcohol [77]; drinking history is associated with being the perpetrator or the victim of violence [78] and alcohol abuse is associated with male-to-female and female-to-male intimate partner violence [79].

However, whilst alcohol may reduce self-regulatory capacities it does not diminish them entirely. Six to thirteen percent of people in the UK or US are classed as being dependent upon alcohol [30,80], which suggests that the vast majority of drinkers are able to regulate their consumption to some degree. A decision to consume alcohol has been conceptualised as the extent to which the motivation to drink is outweighed by the motivation to not drink [81]. Motivation, in the form of a small monetary incentive, can counteract impairments in working memory [82], overcome information-processing deficits [83], and inhibit aggression [84]. Taken together, these findings suggest that sufficient motivation not to consume alcohol may overcome some of the self-regulatory

deficits increased by its consumption. Further ways in which motivation may be increased are discussed in section 1.2.3, below.

1.1.4 Summary

In summary, the motivation to consume alcohol is instigated by positive expectancies; these become associated with cues and from then, cravings to drink are instigated by cues or expectancies or both. Craving strength is likely to be associated with the extent of cue and expectancy reinforcement; i.e., a cue that reliably and strongly signals a positive outcome will increase cravings more than a craving that unreliably signals a positive outcome, or weakly signals a positive outcome, or signals a negative outcome. The consumption of alcohol can make alcohol-related cues more salient and increase cravings to drink and alcohol also impairs the cognitive abilities needed to make rational decisions about whether to instigate or inhibit consumption. The cognitive processing of cues largely occurs outside conscious awareness; however, increasing the motivation not to consume alcohol can reduce impairments in cognitive functioning and may be able to help people regulate their consumption.

1.2 Psychological processes that underpin behaviour change

The expectancy, attentional bias and priming literature suggests that excessive alcohol consumption results from conscious attempts to self-regulate affect and ‘unconscious’ responses to alcohol-related cues. As such, the evidence supports a dual-process model of behaviour, one which argues that alcohol consumption is influenced both by an effortful, reflective and conscious system, and an automatic, impulsive and unconscious system [69].

Many prominent theories consider behaviour to be influenced in predominantly conscious ways. For example, the Theory of Planned Behaviour (TPB) [85] argues that intentions lead reliably to behaviours if an individual considers it more advantageous than not to perform the behaviour

(attitudes), thinks people important to them approve of the behaviour (subjective norms), and believes they have the ability to perform the behaviour (perceived behavioural control). The theory has been criticised for excluding unconscious influences on behaviour and for not accounting for people who intend to act but fail to do so [86]. In response to these criticisms, the author of the theory argued that “the [behavioural, normative and control] beliefs that are accessible in the real situation in which a behaviour is performed can differ from the beliefs that are accessible in the hypothetical situation in which the TPB constructs are typically assessed” (p132 [87]). This explanation appears to render the theory useful only for understanding what an individual intended to do when asked, rather than what they might actually do when, for example, presented with alcohol-related cues.

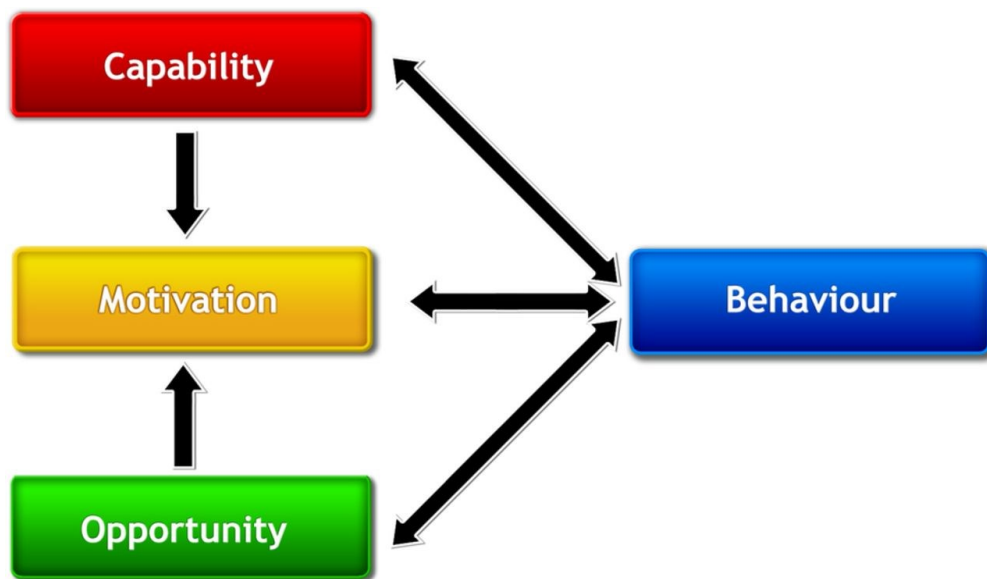
The Transtheoretical Model sees change as a relatively linear process that begins with contemplating a change, moves through preparing and then executing a change until the change is maintained [88]. The proposed utility of the model is that it allows interventions to be tailored to a particular stage in order individuals be moved to stages forward (or, in the final stage, their change maintained), and that doing so increases the recruitment for, retention in and the effectiveness of behaviour change interventions [88,89]. However, more than 40% of smoking cessation attempts are unplanned and these unplanned attempts can be more successful than planned ones [90,91], there is also some evidence to suggest that decisions to seek alcohol treatment may be unplanned [92]. If substantial numbers of people move from contemplation, or even pre-contemplation, to action, the model has limited practical utility and cannot fully explain the psychological processes behind change.

The PRIME Theory of Motivation may explain how intentions do not always lead to actions and why stage models explain only part of the process of change. PRIME Theory’s central principle is that behaviour is determined on a moment-to-moment basis by whichever competing impulse or inhibition is strongest at the time, and that enacting a new behaviour requires activating wants and

needs strong enough to overcome competing impulses or inhibitions [93,94]. PRIME is an acronym for the Plans, Responses, Impulses, Motives and Evaluations which interact to affect motivation [94]. The motivation to perform a behaviour is influenced by Plans to do or not do something; plans influence behaviour when they generate stronger wants and needs (Motives) to perform the behaviour than the wants and needs to not perform the behaviour. Evaluations are consciously or unconsciously made assessments about whether a behaviour 'should' be performed, evaluations influence Motives and Impulses. Impulses and inhibitions are motivational forces that arise from emotional states, drives and stimuli that lead to a desire to perform or not perform the behaviour. Responses are the act of starting, stopping or modifying the behaviour. PRIME Theory explains that intentions do not always lead to action because plans can be thwarted by momentary impulses or inhibitions; and that stage models don't adequately account for how rapidly motives and impulses can change. A recent review of the role of attentional bias in obesity and addiction may provide support for the theory: it concluded that inconsistent evidence of associations between attentional bias and drug use might be explained by momentary changes in evaluations of drug-related stimuli that can either incentivise, discourage or create conflict around drug consumption [95].

PRIME Theory focuses on motivation, which the COM-B model proposes is one of three elements in a system of change. In the COM-B model, for change to occur an individual requires the Capability, Opportunity and Motivation to perform the new Behaviour [96]. Capability is defined as the individual's physical and psychological capability, opportunity is defined as factors external to the individual that prompt the behaviour or make it possible and motivation is defined as the cognitive processes that energise and direct behaviour [96]. Capability, opportunity and motivation influence and are influenced by behaviour. For example, motivation affects the decision to perform a behaviour and successfully or unsuccessfully performing a behaviour affects subsequent motivation toward performing it again (Figure 1.1).

Figure 1.1 – The COM-B model of behaviour



Reproduced with permission from from Michie et al., 2011 [96]

1.2.1 Opportunity

Opportunities to perform a behaviour are usually increased through public health campaigns and/or legislation. A report by the UK's National Institute for Clinical Excellence (NICE) concluded that drink-driving legislation reduces traffic accidents and death and appears to act as a general deterrent to drink-driving [97]. However, individual public health campaigns tend to have a modest effect on behaviour; a meta-analysis of 48 campaigns found in a mean nine percent increase in people performing the behaviour; effect sizes were similar to those for previous meta-analyses of other health behaviour campaigns and were increased when interventions included messages about legal enforcement of the behaviour [98]. Legislation to ban smoking in public places resulted in small reductions in smoking prevalence [99], larger reductions in the risk of coronary events (used as a proxy measure of smoking cessation) [100,101] and a general decrease in the social acceptability of smoking [102].

1.2.2 Capability

One of the key capabilities to regulate consumption is the skill of self-control. The strength model of self-control posits that self-control is a limited resource that can be depleted through exertion [103]. Depleted self-control, termed 'ego-depletion', has been found to reduce task performance and increase perceived difficulty, negative affect and fatigue [104]. However, a reanalysis of a meta-analysis of the effects of ego depletion found strong signals of publication bias in the included studies, which may mean the evidence for ego depletion has been overstated [105]; and a replication study conducted with 23 laboratories found only a small and non-significant effect of ego depletion on task performance [106]. Whilst the replication study has been criticised for using a different experimental procedure than is commonly used to measure ego depletion [107] more replication work is needed to confirm the role of ego depletion on behaviour.

An individual's capability to perform a behaviour can be influenced by self-efficacy, i.e. the amount of confidence they have in their ability to perform the behaviour. Levels of self-efficacy affect the type of goal chosen, the amount of effort and persistence exerted towards a goal and the likelihood of a goal being achieved [108]. Achieving a goal or overcoming obstacles to a goal, or seeing others do so, increases self-efficacy; verbal persuasion can increase self-efficacy, physiological states such as anxiety can be interpreted as a lack of self-efficacy [108]. Low self-efficacy to refuse alcohol has been related to greater frequency and quantity of alcohol consumption [72,109]. Experimentally enhanced self-efficacy can increase subsequent attempts to change smoking, diet, exercise and alcohol behaviours [110].

Capability can be increased by teaching people the skills of forming action or coping plans. An action plan specifies the action(s) that should be taken, and where and when they should be taken, for a goal to be reached [111]. Action plans appear particularly effective when in the form of an implementation intention [112], a pre-specified behaviour scheduled to take place when a situation

that can promote goal attainment is encountered. Implementation intentions consist of an 'if' - the cue to act triggered by a situation or event; and a 'then' - the behaviour. Implementation intentions have been found to have a medium-to-large positive effect on goal attainment across a wide variety of behaviours [113]. A considerable part of their effectiveness appears to arise because the behaviour is automatically triggered whenever the cue is encountered, which reduces cognitive load [113]. The automaticity with which implementation intentions are enacted and the low toll they take on cognitive load may make them particularly suitable for cue-reactive behaviours such as alcohol consumption [68,114].

Coping plans also increase capability by allowing people to develop strategies to maintain a new behaviour in the presence of strong cues to relapse. Coping plans for alcohol reduction or cessation often use the Relapse Prevention Model to help people develop proactive strategies for dealing with situations in which relapse might occur and to respond positively to situations when relapse has occurred [115]. A meta-analysis of 26 published and unpublished studies found that relapse prevention effectively reduced alcohol use and improved measures of psychosocial adjustment (self-ratings of problem severity, coping skill acquisition and self-efficacy) [116]. Coping plans for responding to relapse are theorised by the Abstinence Violation Effect to be more effective if individuals attribute the cause of a relapse to external circumstantial factors rather than internal, stable and global factors [117].

An individual's capability to change behaviour can be cognitively impaired by the consumption of alcohol (as discussed in section 1.1). These impairments arise from alcohol's effect on cognitive processing and from the instigating effect of alcohol-related cues. Cues are related to cravings through learned associations and some evidence suggests that these associations can be unlearned: a meta-analysis found that inhibitory control training, in which appetitive cues are paired with behaviour inhibition, was associated with short-term change in the laboratory [118], heavy drinkers

trained not to attend to alcohol stimuli reported fewer cravings and drank less alcohol than those trained to attend to alcohol stimuli [119] and heavy drinkers could be trained to attend to pictures of soft drinks and avoid alcohol stimuli [120]. However, the overall effects of training on cognitive processes may be limited as training for one set of stimuli did not generalise to novel stimuli [120,121], training effects may be short-lived [122] and a review of interventions that attempted to extinguish associations between instigating cues and the consumption of drugs in addicts found no consistent evidence for their effectiveness [123].

1.2.3 Motivation

Motivation is a core construct in a number of theories of behaviour change. The COM-B model posits that motivation influences and is influenced by behaviour and influences capability and opportunity [96]. PRIME Theory posits that motivational strength is influenced by conscious and unconscious processes and can vary on a momentary basis [94]. The Health Belief Model proposes that change occurs when people consider themselves personally susceptible to a serious risk of ill-health and if they feel the advantages of change outweigh the disadvantages [124]. Self-Determination Theory proposes that motivation arises intrinsically from tasks which meet an individual's need for competence, autonomy and relatedness, or extrinsically from tasks an individual believes they ought or must do to satisfy an external demand or obtain an external reward; intrinsic motivation is considered generally more effective than extrinsic motivation and has been found to lead to greater interest in a task and more confidence in its completion [125]. Regulatory Fit Theory proposes that motivation has a promotion or prevention focus: a promotion focus is concerned with the presence or absence of positive outcomes, a negative focus is concerned with the presence or absence of negative outcomes; and engagement toward goal pursuit is strengthened in individuals when their promotion or prevention focus aligns with the means used to meet their goal [126].

Goals motivate behaviour when they are clearly specified and difficult, but not too difficult, to achieve [127]. Easy goals do not motivate effort [128], vague goals allow for a wide range of acceptable performance and lack a reference point essential for measuring achievement and progress [129]. Proximal goals, goals attainable in the near future, are more motivating than distal, i.e. long-term or far off, goals because they provide clearer feedback about progress [130,131]. Feedback about progress toward proximal goals and the sense of achievement found in reaching them can increase self-efficacy, improve satisfaction with performance and motivate future task persistence [131,132]. Progress feedback is particularly motivating when it indicates the rate of progress toward a goal is below a self-set criterion, when the rate of progress is above the criterion, positive affect arises and effort toward the current goal is reduced in order it be conserved or refocused elsewhere [133]. However, negative affect will only lead to increased effort when the goal is seen as attainable, feedback that suggests the goal is unattainable, or indicates that insufficient progress has been made, can result in goal abandonment [133–136].

Goal abandonment is particularly prevalent in health behaviour change: most attempts to eat better, exercise more, stop smoking, or drink less alcohol are not maintained long-term [137–140].

Rothman's Theory of Behaviour Maintenance proposes that the initiation of a new behaviour is motivated by expectancies about outcomes but behaviour maintenance is achieved only when the outcomes experienced from the new behaviour are greater than or equal to the outcomes expected [141,142]. This suggests that if interventions are to motivate people to maintain their behaviour they need to help them create realistic expectations and ensure that the gains of the new behaviour and/or the losses of returning to the new behaviour are clearly articulated. Evidence in support of the theory comes from the smoking cessation literature: positive expectations predicted the initiation of an attempt to quit smoking but satisfaction with outcomes provided a stronger predictor of sustained cessation [143].

In summary, the psychological processes that underpin behaviour change relate to factors of capability, opportunity and motivation. Opportunity includes government-level creation of new legislation and public health campaigns. Capability is negatively affected by low levels of self-efficacy and alcohol's effect on cognitive processing. It can be positively affected by helping people set suitable plans for action, which help them identify and overcome obstacles to goal attainment, and providing feedback about progress toward goals, which can increase self-efficacy and motivation. Motivation is further increased by the setting of specific and difficult goals. Motivation can be maintained when people are aware of the benefits gained from a new behaviour and what they might lose by returning to the old behaviour.

1.3 Alcohol reduction interventions

Alcohol reduction interventions need not be intensive to have an effect. Brief interventions delivered in primary care settings to those not necessarily seeking help with excessive alcohol consumption [4] are more acceptable to patients, cheaper to provide, and can be as effective as more intensive treatment [4,144,145]. A brief intervention usually consists of one to four sessions of no more than 15 minutes duration, in which a screening questionnaire is followed by feedback on alcohol use, identification of high risk situations for drinking, increasing the patient's motivation to change and development of a personal plan to lower consumption [4]. A 2007 Cochrane review found that brief interventions in primary care reduced alcohol consumption by a mean 38 grams of alcohol per week at one-year follow-up [4]. A 2014 review of 24 systematic reviews of brief interventions in primary care found the effectiveness of the approach to be consistently reported [146]. Brief interventions are recommended by the UK's National Institute for Health and Care Excellence (NICE) as a first step for adults aged 18 and over who have been identified as drinking at hazardous or harmful levels [147] and there have been calls to establish a national centre in the UK to support the implementation and innovation of brief interventions for excessive alcohol consumption [148].

Despite their effectiveness, clinicians have often been reluctant to deliver brief interventions, citing lack of resources, insufficient training, excessive workload and fear of antagonising patients as barriers [149,150]. GPs in England do not routinely enquire about the alcohol consumption of their patients [151] and smokers who visit their GP are up to eight times more likely to receive advice on their smoking than hazardous drinkers are about their drinking [152,153]. GPs can be poor at identifying harmful and hazardous drinkers [154] and sometimes use their own levels of drinking as benchmarks; seeing at-risk drinkers as only those who drink more or differently to themselves [155].

Barriers to implementing brief interventions may also arise from patients who avoid seeking help because they are concerned about the stigma associated with excessive alcohol consumption, have negative experiences with or expectancies about treatment, believe the problem is not severe enough to warrant treatment, or are worried about their privacy [156,157]. Gaining access to treatment can be difficult for some [158], especially those in rural areas [159].

1.4 Advantages of Digital Behaviour Change Interventions

Digital behaviour change interventions (DBCIs), delivered on websites, by email or through mobile phones, may be able to address many of the barriers experienced when delivering brief interventions in person. DBCIs obviate the need for clinician involvement by delivering an intervention directly to an individual. The ability of DBCIs to be accessed wherever the patient is, at whatever time they find suitable and as often as they require, is highly valued by users [160] and increases the likelihood they will make use of the service provided [161].

The anonymity provided by DBCIs allows people to reveal sensitive information they may fear will adversely affect how they are perceived, and enables healthcare providers to access hard-to-reach populations, such as illicit drug users [162], risk-taking adolescents [163] and socially disadvantaged men [164]. Users have described the anonymity and non-judgemental nature of DBCIs as an

important benefit of use [165] and study participants have reported less social anxiety and social desirability [166], more mental health symptoms [167], more disease symptoms [168], more complete HIV risk behaviour [169] and increased reporting of sexual behaviour [170] when using computers compared with pen and paper, telephone, or clinician-administered surveys.

The use of computers in alcohol research has resulted in increased, and potentially more accurate, reporting of alcohol consumption [171]. Users have reported twice as much alcohol use [172,173] and more users have screened positive for problem drinking [174] when using computer-delivered surveys than when the same surveys were delivered by a clinician. Users have also reported a preference for receiving alcohol advice from a computer, with three-quarters of participants stating they would rather feedback about their consumption be delivered on screen than by a medical professional [175].

A qualitative review of 37 DBCIs performed in different health behaviour change domains found that researchers chose to deliver their interventions digitally because they were more convenient for users and more likely to reach people isolated from traditional services; decreased stigmatisation around discussing sensitive health issues; offered the ability to provide timely information; and increased end user and researcher control of the intervention [176]. DBCIs incur a low incremental cost of provision [177,178] and the widespread use of digital devices makes it possible to sample a large and diverse group of users. Once built, DBCIs are easily updated and their ability to deliver different interventions to specific sub-groups of users increases the potential for tailoring interventions to particular user characteristics [179].

1.5 Disadvantages of Digital Behaviour Change Interventions

High rates of attrition are common in DBCIs. The issue is not confined to any particular area of health behaviour change [180] but appears to apply to the use of digital technology across domains [181].

High rates of attrition not only limit the effectiveness of the intervention, since engagement with a health intervention is likely to be a precondition for its effectiveness [182], but also results in large amounts of missing data, which restricts the reliability, validity and generalisability of research findings [183].

DBCIs exist in a competitive environment; as of 2015 over 90 alcohol-reduction apps were available in the UK alone [Chapter 2]. Users choose what they consider to be the best app to suit their needs from the available alternatives [184] and delete those they find unhelpful, unworkable, annoying or unintuitive [185,186]. In cases of open recruitment, where study participation is open to anyone who downloads the app, researchers must, therefore, meet users' needs in a way that differentiates the intervention from the alternatives available in order to maximise the likelihood of it being chosen.

Developing an effective DBCI often requires skills that fall outside the traditional expertise of behavioural science researchers [187], for example copywriting, graphic design and user experience design. The best digital products are built iteratively [188] and involve a process of user testing [189]. The expense incurred in hiring commercial organisations and going through an iterative process of development means that, whilst DBCIs have a low incremental cost, their set-up costs necessitate reaching large numbers of people in order they be cost-effective.

Concerns have been expressed that DBCIs may exacerbate health inequalities [190]. People who use the internet tend to be better educated and have a higher socio-economic status [191,192]; fewer Americans of racial or ethnic subgroups own mobile phones or download health apps [193]. Greater health literacy has been associated with healthier behaviour [194] and increased use of and perceived benefits of healthcare apps [195]. Health literacy is particularly low in people without formal educational qualifications [194]. People with low health literacy can find written health

information difficult to understand and may hold negative views toward preventative healthcare [196,197]. People in general tend to treat health information published online as relatively credible, regardless of source [198,199].

In order to reduce health inequalities it is important to ensure that digital interventions are accessible to people with poorer education and lower socio-economic status; are easy for people with low computer literacy to use; and contain information which is both comprehensible and reliable. Digital health literacy has been defined as “the ability to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem” (Norman and Skinner, 2006, p2 [200]). Therefore, someone with digital health literacy needs not only to be able to use a computer and comprehend the information provided, but also to appraise both its relevance and quality before applying it to their own situation.

Data transferred over the internet can be intercepted and data stored on computers can be stolen. The sensitive nature of the information collected by DBCIs means that important questions about how much and what type of data should be stored, where and how it should be stored, how it should be transmitted and who can access it need to be addressed [201]. Beyond the fundamental principle of appropriate data protection, data security is an important issue to address because of the likelihood that users will stop using a digital service they consider insecure [185].

Whilst the anonymity of DBCIs can result in greater disclosure and reviewers have generally concluded that self-reported estimates of alcohol consumption show adequate reliability and validity [202], issues around self-report remain. For example, studies have found that drinkers can both overestimate and underestimate how much they drink depending whether they are asked to recall their recent consumption [203], or guess how much alcohol would be in a standard unit

[204,205]. DBCIs may be able to address such issues and increase the accuracy of self-report by allowing drinking to be recorded more closely to its point of consumption, enabling drinks to be chosen from preselected lists and using programming to allow only valid responses [202].

1.6 Meta-analyses and systematic reviews of DBCIs for reducing alcohol consumption

Ten meta-analyses and systematic reviews of DBCIs for alcohol reduction have been conducted to date. Of these, nine concluded that DBCIs reduce the amount of alcohol consumed, the frequency with which it was consumed and/or problems related to its consumption, relative to controls [5–7,206–211]. The systematic review that found inconsistent evidence of effectiveness for DBCIs included only one RCT in their analysis [212]. Effect sizes in DBCIs were mostly small (range $d = 0.20$ to $d = 0.42$) and indicated a mean reduction in consumption of approximately 24 grams of alcohol, or three UK units of alcohol, per week (range 12g to 33g).

DBCIs appear particularly effective when compared to assessment only control conditions [5,6,209]. When compared to more active conditions the picture is less clear. Some reviews have found DBCIs to be more effective than providing general information about alcohol [207,208], others found no difference [5,206]. When face-to-face interventions have been compared to DBCIs, face-to-face interventions have been found more effective at reducing the quantity of alcohol consumed, peak levels of blood alcohol content and alcohol-related problems [211].

DBCIs have reduced measures of alcohol consumption relative to controls at follow-up periods ranging from under six weeks [5] to up to a year [208]. The one review which examined follow-ups longer than a year found no statistically significant difference between intervention and controls [208].

Intervention groups frequently received consumption feedback, normative feedback (feedback about how their levels of drinking compare to other people), information about alcohol and its harms and occasionally a more complex intervention involving cognitive behavioural therapy and/or motivational interviewing. Control groups frequently received assessment-only, usual care, no treatment or were wait-list; more active control groups received information about alcohol and its harms or information not about alcohol. Most interventions consisted of a single-session and were generally delivered via the internet, a small minority were delivered via a mobile phone.

Despite evidence of effectiveness for DBCIs, many reviews included studies that wholly or mainly addressed student populations [5,6,208,211,212], and the substantial heterogeneity of outcome measures reported in most reviews [5,6,206–208,210–213], as well as the heterogeneity of intervention content reported in all reviews, limits understanding of how and why interventions are effective. Review authors have consistently called for greater understanding of the mechanisms of action that contribute to intervention effectiveness in order more effective interventions can be developed [5,207,208,210–212].

In summary, it is likely that digital interventions provide small but clinically meaningful reductions in alcohol consumption at a population level. There is little understanding of the mechanisms of action of DBCIs and very few evaluations of apps have been conducted.

1.7 The potential for smartphone apps to support people in limiting their consumption of alcohol

A smartphone is defined as a mobile phone with many of the same capabilities as a computer [214]. According to industry estimates, two billion people worldwide currently own a smartphone, and half of all mobile phone owners are predicted to use a smartphone by 2018 [215]. Smartphones are often carried constantly [216] and used repeatedly [217]; more than 40% of people aged between

18-24 in the UK check their phone immediately before they go to sleep and/or immediately after they awake [218]. Approximately 30% of smartphone owners look at their phone more than 10 times a day, with 12% of young people looking at it more than 100 times a day [219].

The UK has one of the most developed smartphone markets in the world; they are present in more than 66% of all households in the UK [218] and this proportion is rising [220]. Other high income economies have comparable levels of smartphone ownership and show similar trends in growth [221]. Although low and middle income countries do not currently have the same levels of smartphone ownership, the ownership rate is increasing and people in these countries who use a smartphone are more likely to access health-related apps or services than those in high income countries [222].

The widespread adoption and frequent use of smartphones, and in particular the rich functional capacities of the software applications (apps) that run upon them, offer great promise for the provision of innovative healthcare. Apps can enhance disease monitoring, management and education, improve health behaviour assessment and outcomes, increase access to healthcare and facilitate more frequent practitioner-to-user or peer-support communication [223–226]. Apps allow providers to offer a range of healthcare services quickly and cheaply and give users a more convenient and potentially more useful way of finding the help they need than has been possible before [227].

An estimated 250,000 healthcare apps are currently available [228] and increasing numbers of people are turning to apps for their healthcare needs. According to industry reports, healthcare apps were downloaded approximately three billion times in 2015, almost double the number from 2013 [228,229], and more than half the estimated 3.4 billion smartphone users worldwide will have downloaded a healthcare app by 2018 [230]. A third of adult smartphone owners in the US say that

their apps have made them healthier [231]. Fitness or wellness apps are currently used by over 40 million people in the US [232].

1.8 The development and evaluation of apps

The effectiveness of healthcare apps has not been established. A large majority of the apps available for health behaviours as diverse as smoking cessation to melanoma detection are developed without reference to scientific evidence or theory [233] and very few evaluations of apps have been conducted.

1.8.1 App content is rarely evidence based

Apps targeting healthy eating and physical activity are the most frequently available and most in demand type of behaviour change apps [234–236]; however, these apps tend not to make use of behaviour change evidence or theory. Two studies have examined the use of evidence in weight loss apps. In the first, 30 weight loss apps were coded for use of 20 evidence-based behavioural strategies; only 18% of the strategies were used on average and seven of the 20 strategies were not used in any app [237]. In the second study, 204 weight-loss apps were coded for use of evidence-informed guidelines, none of the apps adhered to all 13 guidelines and the majority of apps adhered to no more than two [238]. A study of healthy eating and physical activity apps aimed at US children found that 35 of the 57 apps examined did not include any expert recommendations, and of the apps that did include recommendations, the mean number used was 3.6 out of a possible 15 [239]. Similar results were found in an Australian study of apps aimed at child obesity management; 24 of the 27 apps examined were found not to be based on evidence-informed recommendations [240].

Healthy eating and physical activity apps also tend not to explicitly draw on behavioural theory in their development. The maximum theory-adherence score received by any of 127 exercise apps was 28 out of 100, the mean was 10.0 [241]. The maximum theory-adherence score received by any of

10 popular weight-management apps was 14 out of 100, the mean was 8.1 [242]. The maximum theory-adherence score received by any of 10 popular calorie counting apps was 15 out of 60, the mean was 5.6 [243].

Another popular health domain for healthcare apps is smoking cessation; here too apps tend to be built without reference to evidence. Forty-seven iPhone smoking cessation apps were rated for their adherence to the U.S. Public Health Service's 2008 Clinical Practice Guideline for Treating Tobacco Use and Dependence [244]. The mean adherence score was 7.8 out of a possible 60, no app scored more than 30 and seven scored 0. In a follow-up study, 98 iPhone and Android smoking cessation apps were rated for their adherence to the same guidelines. The mean adherence score was 12.9, out of a possible 42 (the maximum possible score was lower because the coding method had changed) [245]. Apps in both studies failed to follow key recommendations, such as "assess a user's willingness to quit" and "recommend the use of approved medications" [244] or "refer users to a quit line" [245]. Only a minority of apps in the second study provided practical advice on how to stay quit (19%) or gave options for additional support (17%) [245].

Reviews of healthcare apps conducted across a wide range of other health domains have also found that most do not adhere to guidelines, make little use of evidence, are not based on behavioural theory and/or have not involved experts in their development. This applies to apps for asthma [246], bipolar disorder [247], breast disease [248], diabetes [249], eating disorders [250], headaches [251], medical information [252], melanoma detection [253], panic disorders [254] and physical activity [255].

Concern about the content of healthcare apps has led to calls for regulation to improve patient safety [256] and up to 90% of young people want at least some regulation of healthcare apps [257].

In the US, the Federal Trade Commission fined one app \$150,000 for making deceptive claims about its ability to improve a user's vision [258].

1.8.2 Few apps have been evaluated for effectiveness

To date, most evaluations of healthcare apps have been performed on text messaging interventions. Reviews of mobile phone interventions for smoking cessation [259], weight loss [260,261], women's health [262], physical activity [263] and treatment adherence for chronic disease management [264], as well as a review of digital resources for mental health self-management [265], found numerous trials of text messaging but few RCTs of apps.

Where they have been evaluated, apps have generally been found to be effective. A study of the use of a physical activity app over an eight-week period found that the intervention group increased their step count by 2,000 steps per day more than controls (95% CI: 265 to 3,768) [266]. A diabetes management app significantly reduced haemoglobin A1c by 2.03% for the intervention group compared to 0.68% for the controls at three-month follow-up [267]. Apps have also been found to improve muscular fitness, movement skills, and weight-related behaviours [268], reduce healthcare-associated infections [269], promote weight loss [270], increase the self-monitoring of calories [271] and reduce symptoms of depression [272,273].

Few evaluations of alcohol reduction apps appear to have been completed. Reviews of alcohol reduction apps have found four published trials of five apps [274,275]. One app (A-CHESS [276]) was effective in reducing the number of risky drinking days in dependent drinkers (risky drinking days were defined as more than four drinks for men or three drinks for women in a two-hour period). Two apps (LBMI-A [277] and HealthCall-S [278]) demonstrated effectiveness in pilot studies and two apps (Promillekoll and PartyPlanner [279]) were not effective in reducing consumption, in fact users of Promillekoll significantly increased their drinking frequency relative to controls. The approach

used by an additional app, Chimpshop, was effective in laboratory settings and shows promising results [280] but appears not to have been formally evaluated.

1.9 Conclusion: The need for a smartphone app to help people reduce their consumption of alcohol

The problems caused by excessive alcohol consumption for individuals and society highlight the need for more effective and far-reaching interventions. Digital interventions to reduce alcohol consumption appear to be effective and the widespread adoption, accessibility and technological capacities of smartphone apps point to their potential to support people attempting to limit their consumption of alcohol.

However, the lack of evidence about the effectiveness of apps illustrates the need for the rigorous development and evaluation of new smartphone-delivered alcohol interventions. That the overwhelming majority of healthcare apps are developed without reference to evidence or theory suggests there is considerable room for improvement if interventions draw upon behavioural science in their development. This should include reviewing the scientific literature about the effectiveness of various behaviour change techniques (BCTs) and following established procedures for developing DBCIs. In addition to evaluating the effectiveness of the intervention as a whole, the effectiveness of component BCTs should also be evaluated using an appropriate study design.

2 Behaviour change techniques in popular alcohol reduction apps: Content analysis

2.1 Abstract

2.1.1 Background

Smartphone apps have the potential to reduce excessive alcohol consumption cost-effectively.

Although hundreds of alcohol-related apps are available there is little information about the behaviour change techniques (BCTs) they contain, or the extent to which they are based on evidence or theory and how this relates to app popularity and user ratings.

2.1.2 Objectives

To assess the proportion of popular alcohol-related apps available in the UK that focus on alcohol reduction, identify the BCTs they contain, determine the extent to which they use BCTs commonly found in other types of behaviour change interventions and assess whether BCTs or the mention of theory or evidence is associated with app popularity and user ratings.

2.1.3 Method

The Apple App and Google Play stores were searched with the terms 'alcohol' and 'drink' and the first 800 results were classified into: alcohol reduction, entertainment or blood alcohol content measurement or other. Of those classified as alcohol reduction, all 51 free apps and the top 10 paid apps were coded for BCTs and for reference to evidence or theory. Measures of popularity and user ratings were extracted.

2.1.4 Results

Of the 800 apps identified, 662 were unique. Of these, 13.7% were classified as alcohol reduction ($n = 91$; 95% CI: 11.3 to 16.6), 53.9% entertainment ($n = 357$; 95% CI: 50.1 to 57.7), 18.9% blood alcohol content measurement ($n = 125$; 95% CI: 16.1 to 22.0) and 13.4% other ($n = 89$; 95% CI: 11.1 to 16.3).

The 51 free alcohol reduction apps and the top 10 paid apps contained a mean of 3.6 BCTs (SD = 3.4), with approximately 12% (7/61) not including any BCTs. The BCTs used most often were: 'Facilitate self-recording' (54.1%), 'Provide information on consequences of excessive alcohol use and drinking cessation' (42.6%), 'Provide feedback on performance' (41.0%), 'Give options for additional and later support' (24.6%) and 'Offer/direct towards appropriate written materials' (23.0%). These apps also rarely included any of the 22 BCTs frequently used in other health behaviour change interventions (mean: 2.46; SD = 2.06). Evidence was mentioned in 16.4% of apps; theory was not mentioned in any app. Multivariable regression showed that apps including advice on environmental restructuring were associated with lower user ratings ($B = -46.61$; $p = 0.04$, 95% CI: -91.77 to -1.45) and that both the techniques of 'Advise on/facilitate the use of social support' ($B = 2549.21$; $p = 0.04$; 95% CI: 96.75 to 5001.67) and the mention of evidence ($B = 1376.74$; $p = 0.02$, 95% CI: 208.62 to 2544.86) were associated with the popularity of the app.

2.1.5 Conclusions

Only a minority of alcohol-related apps promoted health while the majority implicitly or explicitly promoted the use of alcohol. Alcohol-related apps that promoted health contained few BCTs and none referred to theory. The mention of evidence was associated with more popular apps, but popularity and user ratings were only weakly associated with the BCT content.

2.2 Introduction

Most digital behaviour change interventions (DBCIs) for alcohol reduction have been performed on a computer. Smartphone apps are a new and, due to their technological capacities, widespread adoption and frequent use [219,221], potentially very useful modality for delivering DBCIs.

Approximately 250,000 healthcare apps are available [228], however, the majority are not based on evidence, do not conform to guidelines and tend not to use theory (e.g. [233,236,244]).

Few evaluations of apps have been performed and little is known about their mechanisms of action.

In the absence of such evidence, one approach for exploring the possible mechanisms of action of apps is to perform a content analysis of the BCTs they contain. A BCT is “an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour; that is, a technique is proposed to be an ‘active ingredient’ (e.g., feedback, self-monitoring, and reinforcement)” (p82, [8]). A taxonomy of 42 BCTs to reduce excessive alcohol consumption has been developed from guidance documents and treatment manuals [281]. Other taxonomies have been used to identify the BCTs in smoking cessation apps [282] and physical activity and dietary apps [283,284].

Previous content analyses of alcohol apps have examined the type of app available. A study of alcohol apps in the US Apple App store identified 767 apps, of which 71% (n = 545) were categorised as facilitating the use of alcohol [285]. These apps were mainly drinking games (53%; n = 290), cocktail recipes (16%; n = 86) and bar finders (14%; n = 75). Twenty-nine percent (n = 222) of apps were classed as alcohol reduction, of which 55% (n = 122) were categorised as ‘coping/self-control’, mainly because they facilitated the measurement of a user’s blood alcohol content or kept track of their sobriety date. Twenty percent (n = 45) of the alcohol reduction apps gave feedback on consumption or provided education about the harms of alcohol consumption, and 9% (n = 19) were

categorised as 'social support' in that they gave dependent drinkers information about local 12-step meetings or made it easier for them to call their sponsor [285].

A study of the alcohol apps available in the Australian Apple App Store and Google Play Stores found that of the 384 alcohol-related apps identified, 50% (n = 192) facilitated the use of alcohol [286]. As with alcohol apps in the US, these mainly consisted of drinking games (35%; n = 67), cocktail recipes (31%; n = 60) and bar finders (9%; n = 17). Thirty-nine percent (n = 148) of apps calculated a user's blood alcohol content. Eleven percent (n=44) could be classed as alcohol reduction, 52% (n = 23) of which provided information about the harmful effects of alcohol, outlined alcohol laws or provided information about detoxing, and 45% (n = 20) used hypnosis or other techniques to help people reduce their drinking or stop it entirely [286].

One of the largest categories of apps found by both previous studies were blood alcohol content (BAC) measurement apps. To test the accuracy of the results given, BAC apps available in Australia were populated with real-world data previously collected from a study which had used calibrated breathalysers to measure the BAC of people entering or leaving drinking establishments in five Australian cities; the participant's: gender; age; number of drinks consumed; and number of hours spent drinking was also recorded [286]. Information from four sample profiles, two male and two female, was entered into 98 apps (50 were unavailable, not working or duplicates) and the reading given by the apps was compared against the measured scores from the calibrated breathalysers. The authors found that apps tended to provide inaccurate BAC levels, either because insufficient information was gathered from users to enable an accurate calculation, or because the method of calculation was itself flawed.

This study seeks to build on the work of previous studies by providing an estimate of the relative prevalence of alcohol apps in the UK that focus on reducing alcohol consumption, and by coding

these apps for their component BCTs using an established and reliable method [281]. An additional aim of this study was to identify the extent to which BCTs widely used in other domains are used in alcohol apps. Analysis of the BCTs identified in 40 published descriptions of behaviour change interventions found that 22 of a possible 93 BCTs were frequently used [287]. It would be informative to establish to what degree these 22 BCTs are used in alcohol apps.

The final aim of this study was to examine whether associations exist between the presence of BCTs, or the use of behavioural theory or evidence, with the popularity and user ratings of apps. User ratings influence online and real-world purchasing decisions [288] and are likely to influence the decision to download an app [289–291]. User ratings also affect an app's position in the search results of app store listings [292,293] and apps that appear higher in the listings get downloaded more often [294]. Understanding whether the popularity or user ratings of apps is associated with scientifically informed content may shed light on the ability of app marketplaces to self-regulate, or whether users may benefit from expert guidance about which apps to choose.

Evidence for associations between the scientific base of an app and its popularity or user ratings is mixed. Popular apps (as defined by the approximate number of downloads on the Google Play store or by their position in the search results in the iTunes Store) have been found less likely to adhere to guidelines [244] and less likely to make use of theory [242] than apps not as popular. User ratings have been positively associated with adherence to guidelines in smoking cessation apps [245]. However, no association between user ratings and use of evidence was found in bipolar disorder or weight-loss apps [239,247] and no association was found between popularity and use of evidence in panic disorder apps [254]. Studies which have examined the BCT content of apps have not previously assessed whether associations exist between BCTs and app popularity or user ratings [255,282–284,295,296].

In summary, the research questions addressed by this study are:

1. What proportion of alcohol-related apps available in the UK version of the Apple App Store and Google Play Store focus on alcohol reduction?
2. Which BCTs are contained within alcohol-reduction apps?
3. To what extent do alcohol reduction apps use BCTs commonly found in other types of behaviour change intervention?
4. Do associations exist between the presence of BCTs, the mention of theory or evidence, and the popularity and user ratings of the apps

2.3 Method

2.3.1 Search strategy and data extraction

Alcohol-related apps were identified by searching the UK versions of the Apple App Store and Google Play Store in April and May 2014 for the terms “alcohol” and “drink”. The following data were extracted from the first 200 results found for each term in each app store (4 x 200)¹: time and location of search, app name, developer name, ranking in the search results, cost and classification. Two hundred search results for each search term was deemed comprehensive as users rarely examine search results thoroughly [297].

¹ Neither Google nor Apple make public their algorithms for returning search results. Industry experts suggest the factors affecting ranking are: number of downloads, mean user rating, how long app is retained for and the keywords either specified (Apple App Store) or found in the description of the app (Google Play Store) [292,544].

Duplicate apps were removed from the 800 search results and unique apps were classified as either: alcohol reduction (apps that aim to reduce drinking-related behaviour and those that track consumption), entertainment (drinking games, cocktail recipes, bar finders); BAC measurement; or; other (apps not about alcohol, apps not in English, information for employers etc.).

Of the alcohol reduction apps identified, all free apps were included for detailed coding. Free apps were the focus of this study because users prefer apps which are free to download [298]. However, as a sensitivity check, a small number of paid apps were coded and compared with free apps. Apps that could not be installed or which focussed on hypnosis were excluded. Included apps were coded for the presence of BCTs, mention of theory, mention of evidence, user ratings and number of downloads – where that information was available (downloads are given in bands, e.g. between 10,000 – 25,000 on the Google Play store, no indication of number of downloads is available from the Apple App Store). Ratings were taken from all versions of the app in the Apple App Store (rather than the current version, as is the default option). Coding was not based on any other information, such as descriptions in the app stores or on web pages, or within developer's protocols or published papers.

2.3.2 BCT coding

The taxonomy of BCTs to reduce excessive alcohol consumption and the associated coding manual were used for the present evaluation [281]. The coding manual includes definitions and examples of BCTs and guidelines for identifying them in intervention descriptions (Appendix 8.1 and 8.2). The alcohol-specific taxonomy was chosen in preference to the 93-item taxonomy as the 93-item taxonomy includes BCTs that have been applied to a broader range of health behaviour change interventions and had not been applied to alcohol interventions at the time of this review. For each app, BCTs were coded as 0: no evidence of BCT, 1: BCT present in all probability but evidence unclear; and 2: BCT present beyond all reasonable doubt and clear evidence. For all analyses, the

presence of a BCT was dichotomised, with only BCTs receiving a score of '2' being classified as containing the BCT. The BCT 'build general rapport' was excluded from coding because it could not be appropriately coded for a digital intervention.

The coding manual was used independently by two trained coders to code 11 of the included apps. Strength of agreement between coders met Landis & Koch's (1977) definition of 'substantial' (PABAK = 0.89; κ = 0.65 [299]) for this first round of coding. Discrepancies arising from coding were discussed and the coding guidelines were refined. The remaining apps were coded by one coder with 15% also coded by the second coder to assess rater drift. There was 'almost perfect' strength of agreement for the subsequent ratings of the eight apps coded by both raters (PABAK = 0.89; κ = 0.81 [299]).

Of the 93 BCTs described by a general taxonomy of behaviour change (BCTTv1) [8], 22 have been found to be frequently used in a variety of health behaviour change interventions [287]. In order to establish the extent to which the included apps contained these BCTs, one coder and an independent behaviour change expert mapped the 22 frequently used BCTs to the alcohol taxonomy [281]. This allowed determination to be made of the prevalence with which those BCTs were found in these apps.

The full content of the apps was coded. Alcohol consumption spanning numerous days was entered in order to determine if the app included graphs that displayed progress over time. If the app was tailored on the basis of personal details, the characteristics of a female alcohol consumer in the UK drinking moderately above guidelines were used (30 years, consumed 16 units of alcohol over 3 days in the previous week). Theory was coded if the app made reference to theory as a factor informing its development. Evidence was coded if the app made reference to empirical evidence relating to behaviour change. Apps were coded on an iPhone running iOS7 and a Samsung Galaxy S3 running Android 4.3.

2.3.3 Popularity and user ratings

The popularity of apps was operationalised as the overall number of ratings received. User ratings were operationalised by assessing the proportion of ratings which were 4 or 5 star, and calculating the associated lower 95% confidence interval. Mean ratings were not used because they do not reflect the uncertainty associated with a very small number of ratings [300]. For example, an app with two five star and no other reviews would receive a mean rating of 5 and an app with 900 five star reviews and 100 one star reviews would receive a mean rating of 4.6. Whereas if using a lower bound confidence interval, an app with two five star reviews would have a lower bound CI of 0.34 and an app with 900 five star reviews and 100 one star reviews would have a lower bound CI of 0.88. This approach has been adopted by websites such as reddit and Yelp, which depend on accurately ranking user ratings [301,302].

2.3.4 Analyses

All statistical analyses were conducted using SPSS version 20.0. Frequencies, percentages and associated 95% CIs were calculated for the categories of alcohol-related apps (alcohol reduction, entertainment, blood alcohol content, other), for each of the 41 BCTs, and for the mention of theory or the mention of evidence contained within the alcohol reduction apps. To assess inter-rater reliability Kappa and PABAK were calculated. PABAK is an adjusted Kappa statistic that accounts for coders agreeing on both the presence and the absence of codes [303], and thus supplements Cohen's Kappa, which only accounts for coders agreeing on the presence of codes.

We examined 1) the association between the presence of BCTs and the mention of theory or evidence with the popularity of the app in a series of univariable linear regressions and 2) the independent association after mutual adjustment for all variables in a multivariable linear regression. BCTs only present in two or less apps were excluded. We repeated similar analyses to

examine the univariable and multivariable associations between the presence of BCTs and the mention of theory or evidence with user ratings.

2.4 Results

Of the 800 apps returned from the searches, 662 unique apps were identified (see Figure 2.1). Of these, 13.7% were classified as alcohol reduction ($n = 91$; 95% CI: 11.3 to 16.6), 53.9% entertainment ($n = 357$; 95% CI: 50.1 to 57.7), 18.9% blood alcohol content measurement ($n = 125$; 95% CI: 16.1 to 22.0), and 13.4% other ($n = 89$; 95% CI: 11.1 to 16.3).

2.4.1 BCTs in alcohol reduction apps

A total of 61 apps were coded: all 51 free apps and the first 10 paid apps found in the search results. The remaining paid apps ($n = 15$), apps that could not be installed ($n = 5$) and those which focussed on hypnosis ($n = 10$) were excluded. A sensitivity check indicated that the number and type of BCTs in free and paid apps was broadly similar, so they were treated as a single group. The mean number of BCTs from the alcohol taxonomy [281] used in apps was 3.56 (SD = 3.39; median 2). Seven apps did not include any BCTs and 30 apps (49.2%) included three or fewer BCTs. Five apps included 10 or more BCTs, the maximum number of BCTs included was 13. Twenty-six BCTs were used in at least one app. Details of the apps evaluated and their BCTs can be found in Appendix 8.3 and 8.4.

The frequency with which BCTs were included by different apps is shown in Table 2.1. The most frequent BCTs were: 'Facilitate self-recording' (54.1%; $n = 33$); 'Provide information on consequences of excessive alcohol use and drinking cessation' (42.6%; $n = 26$); 'Provide feedback on performance' (41.0%; $n = 25$); 'Give options for additional and later support' (24.6%; $n = 15$); and 'Offer/direct towards appropriate written materials' (23.0%; $n = 14$).

Table 2.1: BCTs included in alcohol reduction apps

BCT	% (n)
15 Facilitate self-recording	54.1 (33)
1 Provide information on consequences of excessive alcohol use and drinking cessation	42.6 (26)
3 Provide feedback on performance	41.0 (25)
22 Give options for additional and later support	24.6 (15)
32 Offer/direct towards appropriate written materials	23.0 (14)
23 Tailor interactions appropriately	21.3 (13)
2 Boost motivation and self-efficacy	14.8 (9)
14 Prompt review of goals	13.1 (8)
4 Provide rewards contingent on successfully reducing excessive alcohol use/abstaining	13.1 (8)
13 Facilitate goal setting	11.5 (7)
33 Provide information on withdrawal symptoms	9.8 (6)
17 Advise on environmental restructuring	8.2 (5)
42 Behaviour substitution	8.2 (5)
10 Facilitate barrier identification and problem solving	6.6 (4)
11 Facilitate relapse prevention and coping	6.6 (4)
20 Advise on avoidance of social cues for drinking	6.6 (4)
21 Advise on/facilitate use of social support	6.6 (4)
6 Prompt commitment from the user there and then	6.6 (4)
12 Facilitate action planning/know how to help identify relapse triggers	4.9 (3)
25 Assess current and past drinking behaviour	4.9 (3)
5 Provide normative information about others' behaviour and experiences	4.9 (3)
16 Change routine	3.3 (2)
24 Emphasise choice	3.3 (2)
37 Provide reassurance	3.3 (2)
7 Provide rewards contingent on effort or progress	3.3 (2)
8 Identify reasons for wanting and not wanting to reduce excessive alcohol use	3.3 (2)
18 Set graded tasks	1.6 (1)
26 Assess current readiness and ability to reduce excessive alcohol use	1.6 (1)
31 Explain expectations regarding treatment programme	1.6 (1)
9 Explain the importance of abrupt cessation	1.6 (1)

Eleven BCTs were not used in any app: 'Advise on conserving mental resources'; 'Assess past history of attempts to reduce excessive alcohol use'; 'Assess withdrawal symptoms'; 'Elicit and answer questions'; 'Use reflective listening'; 'Elicit user views'; 'Summarise information/confirm user decisions'; 'Model/demonstrate the behaviour'; 'Prompt use of imagery'; 'Motivational interviewing'; and 'General communication skills training'.

2.4.2 BCTs frequently found in other interventions and used in alcohol apps

Of the 22 BCTs frequently found in other health behaviour change interventions, the mean number included in alcohol reduction apps was 2.46 (SD = 2.06; median 2). Of these 22, the five most often included in alcohol apps were: 'Facilitate self-recording' (54.1%; n = 33); 'Provide information on consequences of excessive alcohol use and drinking cessation' (42.6%; n = 26); 'Provide feedback on performance' (41.0%; n = 25); 'Give options for additional and later support' (24.6%; n = 15); and 'Offer/direct towards appropriate written materials' (23.0%; n = 14). Three of the BCTs frequently found in other health behaviour change interventions were not used in any app: 'Motivational interviewing'; 'Use reflective listening'; and 'Model/demonstrate the behaviour'.

2.4.3 Associations between BCTs, theory and evidence with popularity and user ratings

The mean user rating for apps was 2.64 (out of five, SD: 1.71), the mean number of ratings was 234.46 (SD: 1272.08). Evidence was mentioned in 16.4% of apps (n = 10), most usually evidence about the recommended guidelines for the consumption of alcohol. Theory was not mentioned in any app.

The BCT 'Prompt review of goals' (B = 28.34; p = 0.001; 95% CI: 11.88 – 44.79) was positively associated with user ratings in univariable regression models (Table 2.2); no other significant associations between BCTs and user ratings were found. In multivariable linear regression models the only significant association was a negative one: apps that advised on environmental restructuring had marginally lower user ratings (B = -46.61; p = 0.04; 95% CI: -91.77 to -1.45).

Table 2.2: The association between BCTs, theory/evidence with ratings (lower 95% CI of the proportion of ratings > 3/5)

BCT	Unadjusted B (CI)	Adjusted B (CI)
1 Provide information on consequences of excessive alcohol use and drinking cessation	3.68 (-8.59 to 15.96)	-6.54 (-32.64 to 19.56)
2 Boost motivation and self-efficacy	8.26 (-8.78 to 25.29)	17.88 (-9.77 to 45.53)
3 Provide feedback on performance	10.81 (-1.25 to 22.86)	-14.28 (-43.21 to 14.65)
4 Provide rewards contingent on successfully reducing excessive alcohol use/abstaining	12.49 (-5.25 to 30.23)	4.73 (-25.16 to 34.62)
6 Prompt commitment from the user there and then	16.98 (-7.21 to 41.18)	-31.96 (-83.87 to 19.94)
10 Facilitate barrier identification and problem solving	-2.56 (-27.15 to 22.03)	-62.14 (-139.39 to 15.12)
11 Facilitate relapse prevention and coping	15.70 (-39.96 to 8.55)	-17.62 (-94.96 to 59.71)
13 Facilitate goal setting	13.80 (-4.96 to 32.57)	15.19 (-16.26 to 46.64)
14 Prompt review of goals	28.34 (11.88 to 44.79)*	24.34 (-3.67 to 52.34)
15 Facilitate self-recording	8.03 (-4.01 to 20.07)	-0.92 (-27.75 to 25.91)
17 Advise on environmental restructuring	-8.60 (-30.69 to 13.48)	-46.61 (-91.77 to -1.45)*
20 Advise on avoidance of social cues for drinking	5.73 (-18.82 to 30.28)	18.98 (-38.64 to 76.61)
21 Advise on/facilitate use of social support	4.90 (-19.66 to 29.46)	2.39 (-42.95 to 47.73)
22 Give options for additional and later support	2.58 (-11.55 to 16.7)	-2.04 (-44.97 to 40.89)
23 Tailor interactions appropriately	13.30 (-1.16 to 27.76)	-0.89 (-26.32 to 24.54)
32 Offer/direct towards appropriate written materials	0.96 (-13.51 to 15.44)	-16.25 (-50.57 to 18.07)
33 Provide information on withdrawal symptoms	-4.99 (-25.39 to 15.42)	-6.91 (-54.04 to 40.22)
42 Behaviour substitution	-5.50 (-27.65 to 16.65)	-5.25 (-64.82 to 54.32)
Total BCTs	1.13 (-0.66 to 2.91)	6.29 (-13.28 to 25.87)
Mention of evidence	13.80 (-2.25 to 29.85)	18.15 (-3.45 to 39.74)

* indicates $p < 0.05$. BCTs only included for analysis if present in more than two apps. The adjusted models included all variables listed in this table.

The mention of evidence ($B = 881.80$; $p = 0.04$; 95% CI: 24.28 to 1739.31) was positively associated with the popularity of the apps in univariable regression models (Table 2.3). In multivariable linear regression models both 'Advise on/facilitate the use of social support' ($B = 2549.21$; $p = 0.04$; 95% CI: 96.75 to 5001.67) and the mention of evidence ($B = 1376.74$; $p = 0.02$; 95% CI: 208.62 to 2544.86) were positively associated with app popularity.

Table 2.3: The association between BCTs, theory/evidence with popularity (number of ratings)

BCT	Unadjusted B (CI)	Adjusted B (CI)
1 Provide information on consequences of excessive alcohol use and drinking cessation	496.12 (-155.79 to 1148.02)	906.92 (-504.77 to 2318.61)
2 Boost motivation and self-efficacy	-218.08 (-1143.07 to 706.91)	-228.05 (-1723.82 to 1267.72)
3 Provide feedback on performance	516.37 (-138.23 to 1170.96)	410.01 (-1154.91 to 1974.93)
4 Provide rewards contingent on successfully reducing excessive alcohol use/abstaining	-128.72 (-1101.77 to 844.34)	-1362.93 (-2979.54 to 253.69)
6 Prompt commitment from the user there and then	-237.27 (-1563.56 to 1089.02)	-644.43 (-3452.1 to 2163.25)
10 Facilitate barrier identification and problem solving	-243.96 (-1570.16 to 1082.25)	-2150.59 (-6329.64 to 2028.46)
11 Facilitate relapse prevention and coping	-248.5 (-1574.65 to 1077.64)	2175.79 (-2007.23 to 6358.81)
13 Facilitate goal setting	180.87 (-849.23 to 1210.96)	828.87 (-872.37 to 2530.11)
14 Prompt review of goals	134.13 (-838.87 to 1107.13)	-751.26 (-2266.15 to 763.63)
15 Facilitate self-recording	387.05 (-264.74 to 1038.84)	547.11 (-904.17 to 1998.39)
17 Advise on environmental restructuring	-245.59 (-1441.99 to 950.81)	-1189.63 (-3632.18 to 1252.92)
20 Advise on avoidance of social cues for drinking	-238.07 (-1564.35 to 1088.21)	-2799.6 (-5916.7 to 317.49)
21 Advise on/facilitate use of social support	-235.93 (-1562.23 to 1090.37)	2549.21 (96.75 to 5001.67)*
22 Give options for additional and later support	597.28 (-149.92 to 1344.47)	-61.18 (-2383.46 to 2261.1)
23 Tailor interactions appropriately	-182.9 (-984.06 to 618.26)	-778.78 (-2154.21 to 596.65)
32 Offer/direct towards appropriate written materials	647.51 (-115.64 to 1410.65)	666.27 (-1190.03 to 2522.58)
33 Provide information on withdrawal symptoms	-253.57 (-1355.21 to 848.07)	-1868.23 (-4417.4 to 680.94)
42 Behaviour substitution	-244.06 (-1440.49 to 952.36)	-1442.94 (-4665.2 to 1779.31)
Total BCTs	27.23 (-70.01 to 124.48)	150.73 (-908.13 to 1209.58)
Mention of evidence	881.8 (24.28 to 1739.31)*	1376.74 (208.62 to 2544.86)*

* indicates $p < 0.05$. BCTs only included for analysis if present in more than two apps. The adjusted models included all variables listed in this table.

2.5 Discussion

A review of 662 alcohol-related apps in the UK version of the Apple App Store and Google Play Store found that more than half were classified as entertainment apps that promoted drinking, 19% were BAC calculators and 14% had an alcohol reduction focus. This is consistent with findings on alcohol-

related apps available in the US and Australian app stores [285,286] and indicates that potential app users who search for terms such as “alcohol” will be primarily exposed to apps encouraging increased consumption.

The BCTs most often used in alcohol reduction alcohol apps were: 1) ‘Facilitate self-recording’ (included in 54% of apps); 2) ‘Provide information on consequences of excessive alcohol use’ (43%); 3) ‘Provide feedback on performance’ (41%); 4) ‘Give options for additional and later support’ (25%); and 5) ‘Offer/direct towards appropriate written materials’ (23%). The second, fourth and fifth of these are information-based. This finding may indicate a missed opportunity for app developers, as interventions that require interaction from participants have been associated with greater amounts of behaviour change than interventions that passively present information [304].

Behaviour change interventions are often complex and consist of a number of BCTs [9], which may interact additively or synergistically. For example, Control Theory [12] posits that goal-setting, feedback, self-monitoring, action planning and review of goals have synergistic effects; interventions using a group of these techniques have been found to be more effective than interventions using only one [13,14,305]. Commercially available physical activity monitors such as Fitbit and Jawbone, health behaviour change apps and medical adherence apps tend to include many Control Theory congruent BCTs [306–308]. In alcohol reduction apps, ‘Facilitate self-recording’ and ‘Provide feedback on performance’ were frequently used BCTs; however, other BCTs in Control Theory were less often included: ‘Prompt review of goals’ was used in 13% of apps, ‘Facilitate goal setting’ in 12% and ‘Facilitate action planning’ in 5%.

The number of apps prompting the review of behavioural goals was greater than the number that facilitated goal setting as in many cases apps assumed a user’s behavioural goal was to get their drinking below recommended daily or weekly guidelines and displayed a graph to indicate how

current levels of drinking compared to those guidelines. Apps that facilitated goal setting allowed users to set their own goals, e.g. to have a set number of non-drinking days each week. People are motivated by different types of goals [126] and self-set goals can result in greater commitment to goal achievement than assigned goals [309]. These findings suggest that apps which allow users to set their own goals and also to review their performance against them may be more successful, but only three apps met this criteria.

The mean number of BCTs from the alcohol taxonomy [281] included in the apps reviewed in this study was less than four. Five apps included more than 10 BCTs, three of which were book or leaflet-type apps that passively provided information or advice. The relatively low number of BCTs used in the majority of apps suggests there is scope to investigate whether including more BCTs could increase effectiveness. For example, 'Provide normative information about others' behaviour and experiences' has been found effective in reducing alcohol consumption when delivered digitally [310,311], but was used in less than 5% of the apps reviewed in the current study. 'Motivational interviewing' is another frequently used BCT and has been used in a web-based intervention to reduce alcohol consumption [312] indicating the possibility for it to be delivered digitally, but no apps included this technique.

The 22 BCTs frequently found in other health behaviour change interventions [287] were rarely used in alcohol apps (mean: 2.5). Social support is the BCT most frequently found in other interventions but was only used in 7% of alcohol apps. 'Facilitate action planning' is a frequently used BCT in other interventions but was included in less than 5% of apps. Action planning has been found effective when combined with feedback [305], but none of the apps in this study included both techniques.

The current study provided relatively little evidence of association between BCTs, mention of theory or evidence and the popularity or user ratings of apps. The BCT, 'Prompt review of goals', was

positively associated with user ratings in univariable models and 'Advise on environmental restructuring' was negatively associated with user ratings in multivariable models. The mention of evidence was positively associated with the popularity of the app in univariable models and both the mention of evidence and 'Advise on/facilitate the use of social support' were positively associated with popularity in multivariable models. Apps that mentioned evidence usually referred to evidence relating to the recommended guidelines for consumption rather than evidence about the approach to behaviour change adopted by the app. No app mentioned theory.

However, the failure to identify evidence of associations should not be taken as evidence of lack of associations. The relatively small number of alcohol reduction apps available for analysis meant the study was exploratory and had only limited power. It may be that other BCTs are associated with user ratings and popularity, but the large variation in the design, complexity and functionality of apps may be masking such associations [313]. Users may not take the content of an app into account when considering how it should be rated; if it is poorly built and provides a poor user experience it will likely receive negative ratings and few downloads regardless of the BCTs it contains. Careful experimental work in factorial designs is required to isolate and test the impact of BCTs and other app characteristics on effectiveness and app popularity.

2.5.1 Strengths and limitations

Whilst previous studies have examined the type of alcohol-related apps available this is the first to our knowledge to have examined the BCTs present in alcohol apps with an alcohol reduction focus. Documenting their content allows researchers to refine future evaluations in terms of mechanisms of action and may help users to be make more informed choices. It may also allow the future regulation of apps to be facilitated [256,314].

This study has several limitations. First, the presence of a BCT was coded but not its 'dose' [315], that is its intensity and whether or how often it was repeated, nor the quality with which it was delivered [316]. Second, the healthcare app market is constantly evolving; new apps are added on a regular basis and both Google and Apple frequently change their algorithms for returning search results. Therefore, these findings should be seen as representing a snapshot in time. Finally, the BCTs were identified by a taxonomy developed for face to face rather than digital interventions. [281]. Whilst an acceptable inter-rater reliability was established, the list may not be exhaustive and a similar method designed specifically for digital interventions is needed.

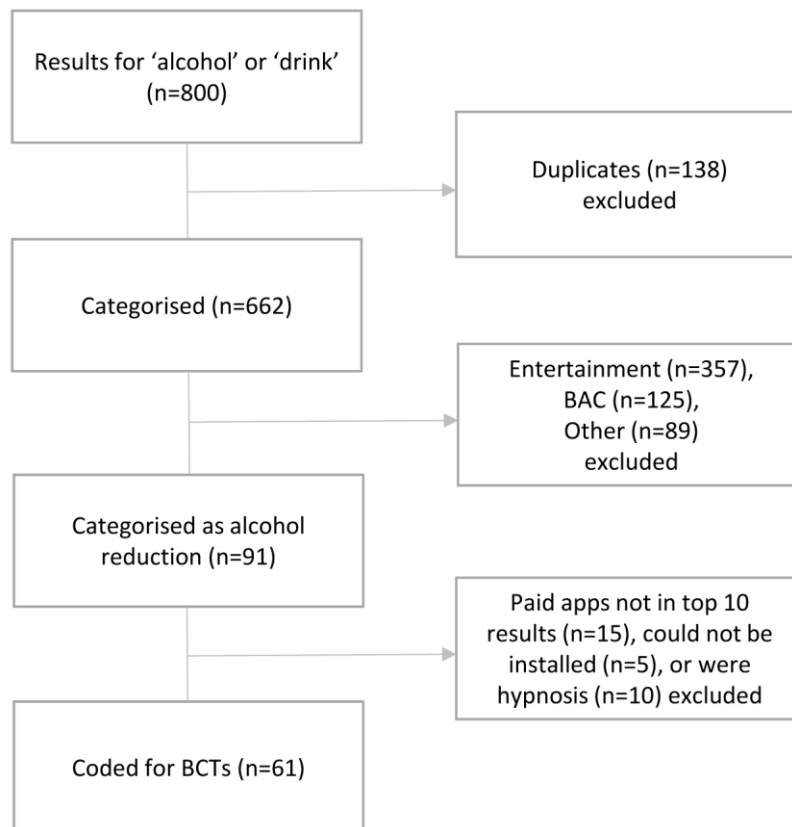
2.5.2 Conclusions

A minority of alcohol-related apps promoted health, the majority implicitly or explicitly promoted the use of alcohol. Alcohol-related apps that focussed on alcohol reduction usually contained few BCTs or few BCTs frequently found in other interventions, and their popularity or user ratings were only weakly related to their BCT content. None of the apps mentioned theory and the few apps that mentioned evidence usually referred to evidence about guidelines; the popularity of these apps suggests that users may value content that makes explicit reference to evidence.

Taken together, these findings suggest the need for an alcohol reduction app which uses BCTs with demonstrated evidence of effectiveness.

Figure 2.1

Flow diagram of apps selected for coding



3 Behaviour change techniques used in digital behaviour change interventions to reduce excessive alcohol consumption: A meta-regression

3.1 Abstract

3.1.1 Background:

Digital behaviour change interventions (DBCIs) appear to reduce alcohol consumption, but greater understanding is needed of their mechanisms of action.

3.1.2 Purpose

To describe the behaviour change techniques (BCTs) used in DBCIs, identify whether individual BCTs are associated with intervention effectiveness, and examine whether the inclusion of more BCTs or more Control Theory congruent BCTs is associated with increased effectiveness.

3.1.3 Methods

Forty-one randomised control trials of alcohol reduction DBCIs were coded for up to 93 BCTs using an established and reliable method. Random effects adjusted and unadjusted meta-regression models were performed to assess associations between BCTs and the effect size of the intervention.

3.1.4 Results

Interventions used a mean 9.2 BCTs (range 1 to 22), 23 different BCTs were used in four or more trials. Trials that used 'Behaviour substitution' (-95.11 grams per week; 95% CI: -162.90 to -27.34), 'Problem solving' (-45.92 grams per week; 95% CI: -90.97 to 0.87) and 'Credible source' (-32.09 grams per week; 95% CI: -60.64 to -3.55) were significantly associated with more greatly reduced alcohol consumption than trials without these BCTs. 'Feedback' was used in 98% of trials (n = 41);

other Control Theory congruent BCTs were used less frequently: e.g. 'Goal setting' 43% (n = 18) and 'Self-monitoring' 29%, (n = 12).

3.1.5 Conclusions

'Behaviour substitution', 'Problem solving' and 'Credible source' were associated with positive alcohol reduction outcomes. Many BCTs were used infrequently in DBCIs, including BCTs with evidence of effectiveness in other domains, such as 'Self-monitoring' and 'Goal setting'.

3.2 Introduction

Digital behaviour change interventions (DBCIs), delivered on websites, by email or through mobile phones, may be able to address the cost, time and training barriers experienced when delivering brief alcohol interventions in person [317,318]. Their convenience and anonymity may reduce patient barriers to seeking help [161,319]. Systematic reviews and meta-analyses have found DBCIs can result in small but meaningful reductions in alcohol consumption, which could have important public health benefits given their low cost and broad reach [5–7,206–211]. However, the heterogeneity of intervention content has led to calls for greater understanding of the mechanisms of action that contribute to intervention effectiveness [5,207,208,210–212].

3.2.1 Identifying the mechanisms of action of interventions

Reliably specifying the BCTs used in interventions allows their active ingredients to be identified, evidence to be synthesised, interventions to be replicated and more effective interventions to be developed [8,320]. A taxonomy of 93 distinct BCTs (BCTTv1) has been developed by consensus methods with input from a large group of international behaviour change experts [8]. Taxonomies have been used to identify the BCTs in physical activity and dietary smartphone apps [283,284], alcohol reduction apps [Chapter 2], wearable activity monitors [306] and internet-based health interventions [321] and have helped systematic reviews progress from treating complex

interventions as a homogenous group [322]. Applying the BCTTv1 taxonomy to digital behaviour change interventions evaluated in RCTs, and assessing associations of included BCTs with effectiveness, could allow the mechanisms of action of DBCIs to be identified, which would be beneficial for future intervention developers.

A recent assessment of the BCTs in alcohol reduction DBCIs by Black, et al. (2016) reported that better outcomes were associated with use of the BCTs of 'Commitment', 'Social comparison', 'Feedback' and 'Review of goals' and worse outcomes were associated with the BCT of 'Providing information on the consequences of alcohol consumption' [323]. However, Black et al. included trials with respondents reporting only moderate consumption, as well as trials where participants were mandated to take part. It is important to determine whether findings generalise when only trials of hazardous or harmful drinkers are included and/or trials where participants mandated to participate are excluded; as the effectiveness of BCTs may be moderated by levels of alcohol consumption, and the motivation to reduce consumption may be greater in people who are not mandated to participate in the intervention. Determining which BCTs are most effective for hazardous and harmful drinkers is particularly important as they are responsible for the majority of health, economic and social costs resulting from alcohol consumption [324]. The current meta-analysis specified interventions using the 93-item taxonomy BCTTv1, rather than the 42-item alcohol-specific one used by Black et al. The 93-item taxonomy was developed across behavioural domains, building on domain-specific taxonomies, including the alcohol one. It is more comprehensive, includes more developed definitions and allows BCTs to be compared across different areas of behaviour change. The wider taxonomy is also more fine-grained, for example, 'Feedback' is elaborated into separate BCTs of 'Feedback on behaviour', 'Feedback on outcome(s) of behaviour' and 'Biofeedback' (e.g. blood alcohol content level) and consequently allows for more specific understanding of the mechanisms of action of interventions.

Behaviour change interventions are often complex and consist of a number of BCTs [9], which may act additively, synergistically, or counteract each other [13,14]. Just as atoms interact to form different molecules, the effectiveness of interventions may be a product of how different BCTs combine. To understand which combinations of BCTs are likely to be effective, we need to turn to theory. Theories provide an analytical framework through which understanding can be gained not just of whether an intervention was effective but also how and why it was effective [10,11]. Control Theory, which states that behaviour is goal-driven and feedback about a discrepancy between current behaviour and a goal leads to behavioural adjustments [12], has been found a promising theory for health behaviour change interventions. Systematic reviews of other domains have found that interventions including more than one of the BCTs in Control Theory ('Goal-setting', 'Self-monitoring', 'Feedback', 'Review of goals' and 'Action planning') resulted in increased physical activity and healthy eating [13,14] and promoted goal attainment [325] more than interventions that only included one technique. Therefore, in addition to examining the BCTs within effective DBCIs, we will investigate whether interventions including more Control Theory congruent BCTs are associated with greater effectiveness in reducing alcohol consumption.

The aims of this review are to:

1. Describe the BCT content of DBCIs to reduce alcohol consumption;
2. Identify whether individual BCTs are associated with the effectiveness of alcohol reduction DBCIs;
3. Examine whether the inclusion of a larger number of BCTs is associated with increased intervention effectiveness; and
4. Examine whether interventions that include more Control Theory congruent BCTs are associated with increased effectiveness.

3.3 Methods

3.3.1 Design

Trials included in a Cochrane review of DBCIs for alcohol reduction [7] were analysed using meta-regression. Cochrane reviews are considered a gold standard for high quality information. Meta-regression is a particularly helpful approach for understanding causes of heterogeneity across divergent interventions and study methodologies. The contribution of this meta-analysis was to reliably code the behaviour change techniques (BCTs) of included interventions. Associations between the inclusion of BCTs and effect size across trials were assessed with unadjusted and adjusted meta-regression.

3.3.2 Identification and selection of trials

Trials selected for inclusion in the Cochrane review were identified by searching electronic databases in health, social science, psychology, education, and human-computer interaction for RCTs of DBCIs to reduce excessive alcohol consumption. Additional searches were performed on relevant web sites considered likely to contain evaluations of DBCIs, for example: the International Alcohol Information Database, Beacon 2.0 and Drug and Alcohol Findings. Databases and sites were searched for terms such as: alcohol drinking; alcohol use; risks; internet; computers; smartphone. Full details of the search strategy can be found elsewhere [7].

3.3.3 Inclusion and exclusion criteria

Trials were included if they were RCTs primarily delivered through a computer or mobile device, directly targeted hazardous and harmful drinkers and aimed to reduce alcohol consumption or harm. Control conditions included no intervention (screening only or screening/assessment); written information about alcohol effects (electronic or printed) and/or consumption recommendations or other health-related advice (not alcohol – as an attention control). Trials were excluded if they were

not RCTs, were directed mainly towards people seeking specialist treatment for their alcohol consumption, or if the intervention was delivered in a secondary or tertiary care setting.

3.3.4 Study sample

The search strategy was performed up to September 2015 and identified 3,163 references. Forty-one trials reported 42 comparisons of DBCIs vs controls with appropriate information to be included in the primary meta-analysis, all of which were coded for BCTs (Figure 3.1). Authors of all included trials were contacted for supplementary materials that may further explain intervention content. Of the forty included trials, 11 authors (27%) could not be contacted, 7 (18%) reported that there was no supplementary materials to send and 22 authors (55%) sent supplementary materials, which were also coded for BCTs.

Of the forty trials, 22 took place in North America, 15 took place in Europe and three in Australasia. Seventeen trials recruited people of any age, 23 recruited students or people aged under 25. The majority of interventions (83%; $n = 33$) were web-based, six (15%) comprised a stand-alone computer programme, one (3%) was a smartphone app.

Forty-one trials reporting the primary outcome measure resulted in 42 comparisons between experimental and control arms. Participants randomised to a digital intervention group drank a mean of 23.6 (95% CI: 16.0 to 31.2) grams of alcohol per week less than controls at end of follow-up. There was considerable heterogeneity in the estimate of the effect size between trials (I^2 : 78%).

3.3.5 Measures

The outcome variable was the mean difference in the quantity of alcohol consumed in a specified time period between intervention and control for each included trial. For trials that did not report it directly, the outcome data on quantity of alcohol consumed was converted to grams per week

(conversion factors reported elsewhere [7]). The exposure variable was whether an intervention included a BCT (dummy coded as 1 = present or 0 = absent for each BCT), the number of BCTs in an intervention, or the number of Control Theory congruent BCTs in an intervention. For trials with more than one control or treatment arm and where these arms were very similar, results for arms were combined in the meta-analysis. Where trials reported these data at more than one follow-up time-point, data was used from the longest follow-up.

3.3.6 Procedure

All trials were coded for BCTs using an established and reliable method [8]. Intervention descriptions were read line-by-line, text that may indicate the presence of a BCT was highlighted, and highlighted text was compared to the definition for the BCT given in the taxonomy [8]. A BCT had to be explicitly present to be coded as included.

The reliability of the method was assessed and improved in iterative rounds of coding. In the first step, two coders independently coded a sample of five trials. Coding differences were resolved through discussion and the coding manual was reviewed and updated in the light of these discussions (Appendix 8.5 and 8.6). If agreement could not be reached, the views of a behaviour change expert were sought. Inter-rater reliability was assessed with both the Kappa and PABAK statistics. Cohen's Kappa accounts for coders agreeing on the presence of codes [299]. PABAK is an adjusted Kappa statistic that accounts for coders agreeing on the presence and the absence of codes [303]. Whilst it is important to measure levels of agreement about the absence of BCTs, using PABAK alone could exaggerate levels of agreement when coding against a taxonomy of 93 BCTs, the large majority of which were likely to be absent in any one intervention [14,283]; therefore, inter-rater reliability was assessed with both statistics. The first round of joint coding led to an inter-rater reliability of $\kappa = 0.73$; PABAK = 0.95, which reflects a substantial level of agreement according to Landis & Koch's (1977) definition [299]. As this exceeded our pre-determined threshold of $\kappa = 0.70$,

remaining trials were coded by one coder, with the second coding 33% (13/40) of the same trials to ensure against rater drift. The inter-rater reliability for all included trials that were joint coded was $\kappa = 0.73$; PABAK = 0.96, which reflects a substantial level of agreement [299].

3.3.7 Analysis

The metareg command in Stata [326] was used to conduct a series of random effects unadjusted meta-regression models to assess the associations between the type, number and combination of BCTs and effect size. Given differences in the recruited samples and designs of the included trials, the assumptions of a fixed effects meta-regression model was assumed to be unlikely to hold. For this reason, a random effects meta-regression model was used to explore variations in alcohol consumption as a function of BCTs. A random-effects meta-regression has the advantage of allowing for residual, unexplained variance in true effects across different trials i.e. for between study variations in effect size. This approach has been recommended previously [327]. The regression coefficients represent the mean of unstandardised effects between trials that differentially included a BCT in the intervention and those which did not (dummy coded as 1 = present or 0 = absent for each BCT). Each unstandardised effect was the mean difference between intervention and control (expressed in grams of alcohol per week). Only BCTs uniquely present in experimental arms, i.e. not present in both experimental and control arms, were included in analysis (BCTs were rarely included in control arms, $m: 0.73$, $SD: 1.66$). To be included in analysis, each BCT needed to be used in at least four separate trials (a criterion used in a previous meta-regression study of the BCTs contained within physical activity and healthy eating interventions [13]). A negative coefficient for a BCT indicated that trials using that BCT produced a larger pooled effect than trials that did not.

To assess the independent association after mutual adjustment, we created an adjusted meta-regression model including all BCTs with a meaningful association with effect size in the unadjusted models (i.e. $B > 23$, which was the lower confidence interval of the effect size reported in a meta-

analysis of the effect of brief advice on alcohol consumption; Kaner et al., 2007 [4]). The associations in the adjusted model were regarded as providing the primary indication of association between BCTs and effect size.

To assess the association between the total number of BCTs included in experimental arms and effect size we created a random effects unadjusted meta-regression model. Lastly, we assessed the overall fit of a model, in terms of adjusted R^2 , containing only a theoretically derived cluster of Control Theory congruent BCTs. These BCTs were grouped into four categories: Goals: 'Goal setting (behaviour)', 'Goal setting (outcome)', 'Review behaviour goal(s)', 'Review outcome goal(s)', 'Discrepancy between current behaviour and goal'; Self-monitoring: 'Self-monitoring of behaviour', 'Self-monitoring of outcome(s) of behaviour', 'Monitoring of emotional consequences'; Feedback: 'Feedback on behaviour', 'Feedback on outcome(s) of behaviour', 'Biofeedback' and Action plans: 'Action planning'. Trials were dummy coded as 1 = used BCTs from three or four of these groupings; or 0 = used BCTs from two or fewer of these groupings.

3.4 Results

The five most frequently used BCTs uniquely present in experimental arms were: 'Feedback on behaviour' (85.7% of trials; $n = 36$), 'Social comparison' (81.0%; $n = 34$), 'Information about social and environmental consequences' (71.4%; $n = 30$) 'Feedback on outcomes of behaviour' (69.0%; $n = 29$) and 'Social support (unspecified)' (64.3%; $n = 27$) (Table 3.1). Full details of the coded studies and their BCTs can be found in Appendix 8.7 and 8.8.

Table 3.1: Frequency of BCTs present in digital behaviour change interventions

BCTs	%age
2.2. Feedback on behaviour	85.7% (36)
6.2. Social comparison	81.0% (34)
5.3. Information about social and environmental consequences	71.4% (30)
2.7. Feedback on outcome(s) of behavior	69.0% (29)
3.1. Social support (unspecified)	64.3% (27)
4.1. Instruction on how to perform the behavior	52.4% (22)
2.6. Biofeedback	50.0% (21)
5.2. Salience of consequences	50.0% (21)
9.2. Pros and cons	35.7% (15)
1.2. Problem solving	33.3% (14)
5.1. Information about health consequences	33.3% (14)
1.4. Action planning	31.0% (13)
9.1. Credible source	31.0% (13)
1.1. Goal setting (behavior)	28.6% (12)
2.3. Self-monitoring of behaviour	26.2% (11)
3.2. Social support (practical)	16.7% (7)
2.4. Self-monitoring of outcome(s) of behaviour	14.3% (6)
4.2. Information about Antecedents	14.3% (6)
1.3. Goal setting (outcome)	11.9% (5)
1.6. Discrepancy between current behavior and goal	11.9% (5)
8.2. Behavior substitution	9.5% (4)
12.2. Restructuring the social environment	9.5% (4)
15.4. Self-talk	9.5% (4)
5.6. Information about emotional consequences	7.1% (3)
7.1. Prompts/cues	7.1% (3)
11.2. Reduce negative emotions	7.1% (3)
12.3. Avoidance/reducing exposure to cues for the behavior	7.1% (3)
1.5. Review behavior goal(s)	4.8% (2)
5.4. Monitoring of emotional consequences	4.8% (2)
10.3. Non-specific reward	4.8% (2)
10.9. Self-reward	4.8% (2)

1.7. Review outcome goal(s)	2.4% (1)
1.8. Behavioral contract	2.4% (1)
3.3. Social support (emotional)	2.4% (1)
4.4. Behavioral experiments	2.4% (1)
8.1. Behavioral practice/rehearsal	2.4% (1)
8.4. Habit reversal	2.4% (1)
8.7. Graded tasks	2.4% (1)
10.4. Social reward	2.4% (1)
10.6. Non-specific incentive	2.4% (1)
13.2. Framing/reframing	2.4% (1)
14.2. Punishment	2.4% (1)
15.1. Verbal persuasion about capability	2.4% (1)
15.3. Focus on past success	2.4% (1)

The following BCTs were not used in any DBCI: 1.9. Commitment, 2.1. Monitoring of behaviour by others without feedback, 2.5. Monitoring of outcome(s) of behaviour without feedback, 4.3. Re-attribution, 5.5. Anticipated regret, 6.1. Demonstration of the behaviour, 6.3. Information about others' approval, 7.2. Cue signalling reward, 7.3. Reduce prompts/cues, 7.4. Remove access to the reward, 7.5. Remove aversive stimulus, 7.6. Satiation, 7.7. Exposure, 7.8. Associative learning, 8.3. Habit formation, 8.5. Overcorrection, 8.6. Generalisation of target behaviour, 9.3. Comparative imagining of future outcomes, 10.1. Material incentive (behaviour), 10.2. Material reward (behaviour), 10.5. Social incentive, 10.7. Self-incentive, 10.8. Incentive (outcome), 10.10. Reward (outcome), 10.11. Future punishment, 11.1. Pharmacological support, 11.3. Conserving mental resources, 11.4. Paradoxical instructions, 12.1. Restructuring the physical environment, 12.4. Distraction, 12.5. Adding objects to the environment, 12.6. Body changes, 13.1. Identification of self as role model, 13.3. Incompatible beliefs, 13.4. Valued self-identify, 13.5. Identity associated with changed behaviour, 14.1. Behaviour cost, 14.3. Remove reward, 14.4. Reward approximation, 14.5. Rewarding completion, 14.6. Situation-specific reward, 14.7. Reward incompatible behaviour, 14.8. Reward alternative behaviour, 14.9. Reduce reward frequency, 14.10. Remove punishment, 15.2. Mental rehearsal of successful performance, 16.1. Imaginary punishment or 16.2. Imaginary reward

Of the ninety-three possible BCTs that could have been used, 15 were used in more than 20% of trials, 44 were used at least once and 49 were never used. The mean number of BCTs used in experimental arms was 9.2 (SD = 5.3), the median was 9 and the range 1 to 22.

The prevalence of Control Theory congruent BCTs was as follows: Goals: 'Goal setting (behaviour)' (28.6% of trials; n = 12), 'Goal setting (outcome)' (11.9%; n = 5), 'Discrepancy between current behaviour and goal' (11.9%; n = 5), 'Review behaviour goal(s)' (4.8%; n = 2), 'Review outcome goal(s)' (2.4%; n = 1). Self-monitoring: 'Self-monitoring of behaviour' (26.2%; n = 11), 'Self-monitoring of outcome(s) of behaviour' (14.3%; n = 6), 'Monitoring of emotional consequences' (4.8%; n = 2). Feedback: 'Feedback on behaviour' (85.7%; n = 36), 'Feedback on outcome(s) of behaviour' (69.0%; n = 29), 'Biofeedback' (50.0%; n = 21). 'Action planning' (31.0%; n = 13).

In unadjusted models (Table 3.2), the BCTs of 'Behaviour substitution' (-123.71 grams per week; $p < 0.001$; 95% CI: -184.63 to -62.80; R^2_{adj} : 48.53%), 'Information about antecedents' (-74.20 grams per week; $p < 0.01$; 95% CI: -117.72 to -30.68; R^2_{adj} : 32.15%), 'Problem solving' (-48.03 grams per week; $p < 0.01$; 95% CI: -77.79 to -18.27; R^2_{adj} : 25.01%), 'Goal setting (behaviour)' (-43.94 grams per week; $p = 0.01$; 95% CI: -78.59 to -9.30; R^2_{adj} : 6.64%) and 'Credible source' (-39.89 grams per week; $p = 0.02$; 95% CI: -72.66 to -7.11; R^2_{adj} : 15.60%) were all associated with greater reduced alcohol consumption. No other BCTs were significantly associated with reduced consumption in the unadjusted models. The total number of BCTs present in the intervention was also not significantly associated with reduced consumption in the unadjusted models (-2.71 grams per week; $p = 0.07$; 95% CI: -5.65 to 0.23; R^2_{adj} : 3.26%).

Table 3.2: Unadjusted associations between BCTs and the unstandardized effect size of the intervention

BCT	MGPW (SE)	N	P	95% CI	I ²	Adj R ²
1.1 Goal setting (behavior)	-43.94 (17.14)	12	0.01*	-78.59 to -9.30	78.05%	6.64%
1.2 Problem solving	-48.03 (14.72)	14	<0.01*	-77.79 to -18.27	74.64%	25.01%
1.3 Goal setting (outcome)	-14.43 (23.46)	5	0.54	-61.85 to 32.99	77.71%	-2.95%
1.4 Action planning	-26.21 (16.58)	13	0.12	-59.73 to 7.30	77.57%	5.45%
1.6 Discrepancy between current behaviour and goal	-33.88 (24.97)	5	0.18	-84.35 to 16.58	78.24%	0.15%
2.2 Feedback on behavior	12.97 (21.30)	36	0.55	-30.08 to 56.02	78.31%	-7.13%
2.3 Self-monitoring of behavior	-30.39 (17.14)	11	0.08	-65.03 to 4.26	78.36%	2.07%
2.4 Self-monitoring of outcome(s) of behavior	-8.60 (22.37)	6	0.70	-53.81 to 36.61	78.52%	-4.67%
2.6 Biofeedback	10.81 (15.24)	21	0.48	-19.99 to 41.62	77.85%	1.55%
2.7 Feedback on outcome(s) of behavior	-4.62 (16.45)	29	0.78	-37.87 to 28.63	78.48%	-5.63%
3.1 Social support (unspecified)	-19.55 (15.39)	27	0.21	-50.65 to 11.55	78.53%	-0.41%
3.2 Social support (practical)	-26.35 (22.59)	7	0.25	-72.01 to 19.31	77.18%	0.29%
4.1 Instruction on how to perform the behavior	4.46 (15.51)	22	0.78	-26.89 to 35.80	78.55%	-5.77%
4.2 Information about antecedents	-74.20 (21.53)	6	<0.01*	-117.72 to -30.68	74.91%	32.15%
5.1 Information about health consequences	16.75 (15.70)	14	0.29	-14.99 to 48.49	78.42%	0.06%
5.2 Salience of consequences	21.99 (14.86)	21	0.15	-8.05 to 52.02	78.17%	4.92%
5.3 Information about social and environmental consequences	28.88 (16.56)	30	0.09	-4.59 to 62.34	77.59%	1.01%
6.2 Social comparison	24.25 (18.95)	34	0.21	-14.06 to 62.56	78.53%	-4.98%
8.2 Behavior substitution	-123.71 (30.14)	4	<0.001*	-184.63 to -62.80	72.92%	48.53%
9.1 Credible source	-39.89 (16.22)	13	0.02*	-72.66 to -7.11	75.84%	15.60%
9.2 Pros and cons	-30.10 (15.77)	15	0.06	-61.97 to 1.78	77.57%	10.15%
12.2 Restructuring the social environment	-22.91 (31.52)	4	0.47	-86.62 to 40.79	78.56%	-7.66%
15.4 Self-talk	-41.53 (26.37)	4	0.12	-94.84 to 11.77	77.93%	6.04%

* indicates $p < 0.05$. MGPW (SE) = mean grams per week (standard error). BCTs only included in analysis if present in at least four trials. Results from the standardised model were broadly similar to the unstandardised model; as a result, data are only reported from the unstandardised model.

In an adjusted model that included BCTs with a $B > 23$ in the unadjusted model, the BCTs of 'Behaviour substitution' (-95.12 grams per week; $p = 0.01$; 95% CI: -162.90 to -27.34), 'Problem solving' (-45.92 grams per week; $p = 0.05$; 95% CI: -90.97 to -0.87), and 'Credible source' (-32.09 grams per week; $p = 0.03$; 95% CI: -60.64 to -3.55) were significantly associated with reduced alcohol consumption (Table 3.3). The adjusted meta-regression model produced relatively good indices of fit and reduced heterogeneity (I^2 : 67.24%; R^2_{adj} : 59.51%, $p < 0.01$) compared to the I^2 heterogeneity of 78.0% from the primary meta-analysis [7].

Table 3.3: Adjusted associations between BCTs and the unstandardised effect size of the intervention

BCT	B (SE)	P	95% CI
1.1 Goal setting (behavior)	0.75 (19.60)	0.97	-39.40 to 40.89
1.2 Problem solving	-45.92 (21.99)	0.05*	-90.97 to -0.87
1.4 Action planning	30.75 (19.50)	0.13	-9.19 to 70.68
1.6 Discrepancy between current behaviour and goal	-29.86 (23.97)	0.22	-78.97 to 19.25
2.3 Self-monitoring of behavior	-6.34 (18.35)	0.73	-43.91 to 31.24
3.2 Social support (practical)	33.73 (21.85)	0.13	-11.03 to 78.49
4.2 Information about antecedents	-43.38 (23.93)	0.08	-92.39 to 5.63
5.3 Information about social and environmental consequences	24.64 (12.17)	0.05	-0.30 to 49.57
6.2 Social comparison	3.92 (13.11)	0.77	-22.93 to 30.77
8.2 Behavior substitution	-95.12 (33.09)	0.01*	-162.90 to -27.34
9.1 Credible source	-32.09 (13.94)	0.03*	-60.64 to -3.55
9.2 Pros and cons	6.68 (13.68)	0.63	-21.33 to 34.69
15.4 Self-talk	-8.41 (26.69)	0.76	-63.09 to 46.27

* indicates $p < 0.05$

Only BCTs with $B > 23$ in the unadjusted analysis included in the adjusted analysis

A total of 16 trials used BCTs from three or four of the groupings of Control Theory BCTs. These trials were weakly associated with effectiveness (-30.76 grams per week; $p = 0.06$; 95% CI: -62.35 to 0.83) and the model produced a poor index of fit and did not improve the heterogeneity from the primary meta-analysis (Heterogeneity: $I^2 = 78.03\%$; $R^2 = 1.81\%$).

3.5 Discussion

The BCTs of 'Behaviour substitution', 'Problem solving' and 'Credible source' were significantly associated with a reduction in grams of alcohol consumed per week in both unadjusted and adjusted random effects models. The mean number of BCTs used in interventions was 9.2 (SD = 5.3), the median was 9 and the range 1 to 22, and a total of 23 different BCTs were used in at least four trials. By comparison, the mean number of BCTs used in popular alcohol reduction apps was four [Chapter 2]. No significant association between the number of BCTs used and intervention effect was found, nor was there a significant association between use of more Control Theory congruent BCTs and intervention effect.

'Behaviour substitution', defined as "Prompt substitution of the unwanted behaviour with a wanted or neutral behaviour" [8] was associated with a mean reduction in drinking of 12 UK units of alcohol per week (a UK unit consists of 8 grams of alcohol). The BCT was present in four trials ([328–330], one paper reported two trials), three of which were performed by the same research group who implemented the technique in the same way; asking participants to: 1) Reflect on the pros and cons of drinking; 2) Detail the outcomes expected from drinking; and 3) Select behaviours that could provide an acceptable alternative to drinking. 'Behaviour substitution' is a BCT recommended by guidance documents and treatment manuals for use in alcohol reduction [281], was considered the fifth most important BCT for inclusion in an alcohol reduction app by alcohol and behaviour change experts [16] and has been widely used in a variety of health behaviour change interventions, for example: physical activity [331], healthy eating [332], safer sex [333] and smoking cessation [334].

‘Problem solving’, defined as “Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators” [8] was associated with a mean reduction in drinking of six UK units of alcohol per week. The BCT was present in 14 trials [178,328–330,335–343], half of which adopted a Relapse Prevention or Coping Planning approach. Relapse Prevention and Coping Planning both aim to promote behaviour maintenance by helping people develop proactive strategies for dealing with situations in which relapse might occur; Relapse Prevention additionally aims to help people react positively to situations when relapse has occurred [115,344]. A notable characteristic of ‘Problem solving’ and ‘Behaviour substitution’ is that these BCTs help people who are engaged in self-directed behaviour change identify practical and specific ways of reaching their drinking reduction goals. The potential effectiveness of these BCTs suggests that DBCIs may be enhanced when users are given guidance and direction about how to maintain behaviour change, particularly when that comes from a source perceived to be credible.

‘Credible source’, defined as “Present verbal or visual communication from a credible source in favour of or against the behaviour” [8] was associated with a mean reduction in drinking of four UK units of alcohol per week. The BCT was present in 13 trials [328–330,338,339,341,345–350] and generally consisted of advice about national guidelines for consumption, or advice about drinking provided by a member of the study. Despite more than 30 nations providing alcohol consumption guidelines [351], a review of governmental policies to reduce alcohol-related harm found that no evaluation of their effectiveness had been published [352]. The credibility of a source has consistently been found to affect the persuasiveness of information delivered via traditional media [353,354]. When health information is delivered online users can be indiscriminating in their assessment of which sources are credible [198,199]. Evidence from this review and from a review of the BCTs in alcohol-reduction apps [Chapter 2] suggests that people may value guidance from a

credible source about the maximum amount of alcohol they should consume. Further investigation of the effectiveness of providing such information in DBCIs is warranted.

Findings from this study differ to a recent assessment of the BCTs in alcohol DBCIs (Black et al. 2016), which found that the BCTs of 'Commitment', 'Social comparison', 'Feedback' and 'Review of goals' were associated with better outcomes and the BCTs of 'Providing information on the consequences of alcohol consumption' was associated with worse outcomes [323]. There are at least two reasons why the two trials may have found different BCTs to be associated with effectiveness. Firstly, studies were only included if they related to our populations of interest. Most notably trials were only included where participants were not mandated to take part and where they were known (via a specific screening process) to be drinking at harmful and hazardous levels; whereas Black et al. included mandated participants and all drinkers regardless their level of consumption. As a consequence, only 27 trials analysed here were also analysed by Black et al. Secondly, the 93-item taxonomy includes a BCT of 'Credible source' (the 42-item taxonomy does not), and has three 'Feedback' BCTs, two 'Review goal' BCTs and three BCTs that provide information on negative consequences of performing a behaviour; whereas the 42-item taxonomy only has one BCT for each. Replication work using the same taxonomy on the same or different data sets may help determine which BCTs are effective in DBCIs and whether there are differences in BCTs that are effective across different populations.

Nearly all trials gave feedback in one form or another. 'Feedback on behaviour', which usually consisted of information about levels and/or patterns of drinking, was the most popular BCT, 'Feedback on outcomes of behaviour, which usually consisted of information about the health risks or other negative consequences that might occur should the participant's drinking continue at its current level, was the fourth most popular BCT and 'Biofeedback', which consisted of information about recent levels of blood alcohol content was the eighth most popular BCT. The widespread

inclusion of feedback is not unexpected. The provision of feedback was an inclusion criteria for studies in the Cochrane review [8]. Only one trial was coded as not including feedback because it was a three-arm trial, of which only the arm which tested a decisional balance exercise was included in the final Cochrane analysis.

Other frequently used BCTs were: 'Social comparison', which involved presenting a participant with information comparing their drinking with that of their peers; 'Information about social and environmental consequences', which was often coded alongside 'Feedback on outcomes of behaviour' as interventions commonly provided feedback about the potential negative consequences of the participant continuing to drink at their current level; and 'Social support (unspecified)', which often involved the provision of links to services that might further help a participant reduce their drinking.

Some BCTs with evidence of effectiveness in other behavioural domains were used infrequently. For example, 'Self-monitoring of behaviour', defined as "Establish a method for the person to monitor and record their behaviour(s) as part of a behaviour change strategy" [8] has been found effective for a variety of health behaviours [13,273,355–359]. A reanalysis of a Cochrane review of face-to-face brief alcohol interventions found that interventions which included self-monitoring were associated with larger effect sizes [281]. However, participants in only a quarter of the digital trials in this review were asked to self-monitor their drinking as part of the intervention, despite the ability of DBCIs to facilitate the easy, ongoing and anonymous recording of consumption. Similarly, the BCTs: 'Facilitate goal setting' and 'Review of behavioural goals' have been found effective in other health behaviour interventions [13] and were frequently used BCTs in face-to-face interventions to reduce excessive alcohol consumption [281]. However, less than a third of trials in this study used the BCT of 'Goal setting (behaviour)', five trials used the BCT of 'Goal setting (outcome)' and only three used either 'Review behaviour goal(s)' or 'Review outcome goal(s)'.

There are 93 BCTs in the taxonomy: 23 were used in more than four DBCIs, 44 were used in at least one and 49 were not used in any. BCTs in the taxonomy are grouped into 16 different categories; DBCIs used all 'Social Support' and almost all 'Goals and Planning', 'Feedback and Monitoring', 'Shaping Knowledge', 'Natural Consequences', 'Comparison of Behaviour', 'Comparison of Outcomes' and 'Self-belief' BCTs. DBCIs used few 'Associations', 'Regulation', 'Antecedents', 'Identity' and 'Scheduled Consequences' BCTs, and no 'Covert Learning' BCTs. The lack of use of many BCTs in the taxonomy suggests that DBCIs could utilise many more BCTs than have currently been included and evaluated.

Evidence that the use of more BCTs improves intervention effectiveness is mixed. Interventions targeted at lower-income groups which aimed to increase physical activity and/or healthy eating, or reduce smoking were found to be more effective when they contained fewer BCTs [360]. Other reviews have found that interventions which included more BCTs tended to have larger effect sizes [321,361]. A factorial trial, in which different groups of participants are given different numbers of BCTs, may be necessary to answer this question empirically.

Control arms included a mean 0.73 BCTs. The BCTs most commonly included were those that provided information about the social, environmental, health and emotional consequences of consumption, and those that provided feedback about consumption or the consequences of consumption, feedback about the amount of alcohol peers consumed in comparison to their own consumption, or feedback about their blood alcohol concentration levels. Nine control arms included one or more BCTs, 32 included no BCTs at all. A BCT is defined as "an observable, replicable, and irreducible component of an intervention designed to alter or redirect causal processes that regulate behaviour; that is, a technique is proposed to be an 'active ingredient'" (p82, [8]). BCTs were only coded as present in an intervention if they were uniquely present in the experimental arms. It is therefore possible that the nine interventions which included any BCTs inadvertently

created an active control group. This would have limited the ability of the intervention to find an effect of the BCT and made it more difficult for this study to determine the effectiveness of those BCTs on alcohol reduction.

The finding of a weak association between use of more Control Theory congruent BCTs and intervention effect differs from reviews which found that interventions using more Control Theory BCTs ('Goal-setting', 'Self-monitoring', 'Feedback', 'Review of goals' and 'Action planning') resulted in greater physical activity and healthy eating [13], greater weight loss [14] and increased goal attainment [325]. The lack of an effect may reflect the importance of increasing motivation rather than improving self-regulation for people wishing to reduce their consumption of alcohol. Alcohol diminishes self-regulatory capacities; it increases impulsivity, impairs inhibitory control, and increases attentional bias for alcohol-related cues [48,60,68,362]. Greater motivation to not drink may moderate cravings for alcohol [68,363]. It is possible, therefore, that increasing the motivation to reduce consumption may be a more effective behaviour change strategy for DBCIs than increasing self-regulation skills, which may be diminished by the consumption of alcohol.

3.5.1 Strengths and Limitations

To our knowledge, this is the first study to use the comprehensive 93-item taxonomy to examine the effectiveness of BCTs in alcohol reduction DBCIs. Given the increasing number of these interventions and the lack of understanding about their mechanisms of action, our analysis is an important step in the accumulation of evidence on the effectiveness of component BCTs, and the contrast of our findings with Black et al. (2016) demonstrates the need for replication. The inclusion of these BCTs within standalone interventions, or as individual modules within a larger intervention, warrants further investigation in an experimental context.

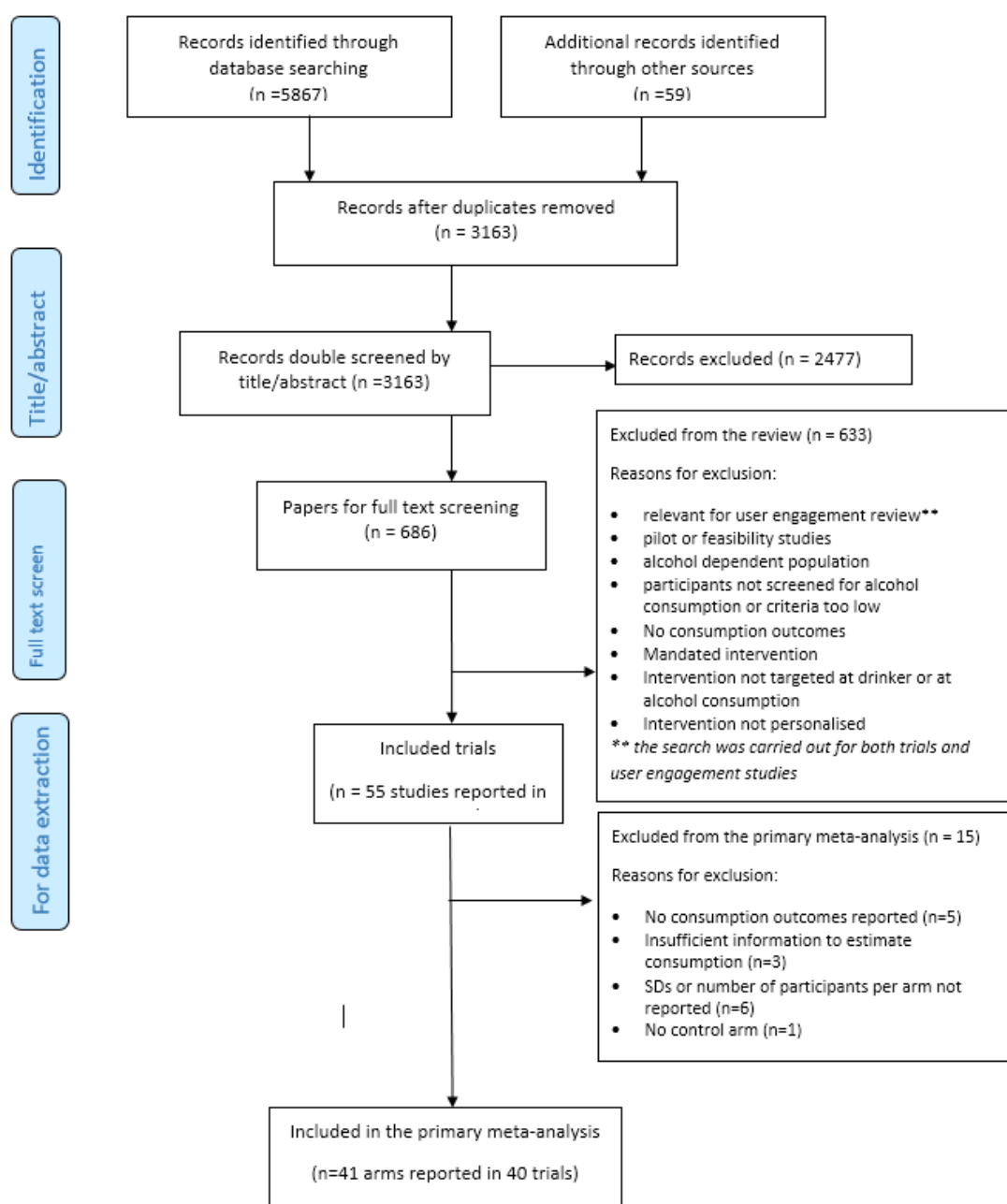
However, one major limitation with meta-regression is that study characteristics are often highly correlated leading to issues with multicollinearity [326]. There was some evidence in this study that BCTs tended to cluster together in papers. However, other indicators of possible multicollinearity were not present: there was no evidence of extremely large standard errors or large changes in coefficients caused by the deletion or addition of BCTs [364]. The total number of BCTs included in the final multivariate meta-regression was also small which limits collinearity effects. Nonetheless, caution should be taken when interpreting the coefficients directly [364]. In view of these limitations, some researchers may judge the pattern of results in the unadjusted models as most important. In addition, failure to identify evidence for associations should not be taken as evidence for the null hypothesis of no effect. The small number of interventions available for analysis and the infrequent use of many BCTs (70 of the 93 BCTs were used less than four times) meant that the possible effects of most BCTs could not be evaluated. It is unclear whether BCTs are missing because they were not reported as included or because they were not included in the intervention in the belief that they were not useful. Other BCTs were used so frequently ('Feedback on behaviour' and 'Social comparison' were both present in more than 80% of trials) as to reduce the ability to assess their association with effectiveness. The potential for robust conclusions is also limited by the modest sample size and by the quality of reporting; recognised issues with the incomplete reporting of intervention content [365] may have resulted in BCTs being incorrectly coded as present or absent. This introduces noise, increases the potential for bias due to misclassification and undermines the power to test associations. To resolve this, authors should be encouraged to report intervention content in sufficient detail for accurate coding of BCTs to be achieved, using the BCTTv1 [8] to allow for comparison across behavioural domains. Moreover, simply recording a BCT as present or absent does not take into account the frequency, intensity or form in which it was delivered. The form of a DBCI, i.e. the way the intervention is presented, its ability to meet user needs and the user experience that results from its use [366] are likely to play an important role in

the depth and length of user engagement with a BCT. Greater understanding of the 'dose' [316] of a BCT, its quality of delivery [367] and how it acts in combination with other BCTs is needed in order to fully evaluate its effectiveness. The relationship described by a meta-regression is an observational association across trials, any identified association with one characteristic of the trial may in reality reflect a true association with other correlated characteristics, whether these are known or unknown. The finding of the effectiveness of the BCT of 'Behaviour substitution' should be treated as preliminary, as the BCT was only used in four trials, three of which reported large effects and were conducted by the same research group using the same implementation. Greater understanding of the effectiveness of this BCT across settings and in other domains and interventions is required to support the generalisability of this finding.

3.5.2 Conclusions

The BCTs of 'Behaviour substitution' 'Problem solving' and "Credible source' as reported in intervention descriptions were associated with stronger effectiveness of digital behaviour change interventions to reduce alcohol consumption and warrant further investigation in an experimental context. Other BCTs, such as 'Self-monitoring', 'Goal setting' and 'Review of behavioural/outcome goals', were rarely used in the trials included in this review, despite good evidence of effectiveness in other behaviour change domains, as detailed in the following chapter.

Figure 3.1: Flow chart of trials



Reproduced with permission from: Personalised digital interventions for reducing hazardous and harmful alcohol consumption in community-dwelling populations [7]

4 Development of a smartphone app to reduce excessive alcohol consumption

4.1 Selecting the behaviour change techniques (BCTs) for evaluation

Self-monitoring, feedback, action planning and goal setting are considered an essential part of self-regulation in a number of behaviour change theories, including Control Theory, Self-regulation Theory and Social Cognitive Theory [12,368,369]. In each, self-regulation is conceptualised as a process in which a goal or standard is established, self-monitoring and feedback are used to determine the current position in relation to the goal as well as progress toward it, and action plans are employed to reduce discrepancies between the current position and the goal.

The UK's National Institute for Clinical Excellence (NICE) recommends that to be effective, behaviour change interventions should include the BCTs of self-monitoring, feedback, action planning and goal setting [15]. These were also the four BCTs identified in a consensus exercise amongst alcohol and behaviour change experts as most likely to be effective in an alcohol reduction app [16].

This chapter presents the theoretical basis and further evidence for the BCTs selected for evaluation, describes how the BCTs have been implemented in other DBCIs and suggests ways in which their implementation in apps may increase their effectiveness.

4.2 Self-monitoring and feedback

4.2.1 Theoretical basis and evidence for the effectiveness of self-monitoring and feedback

Self-monitoring is the act of noticing and recording goal-related behaviour [370]. Self-monitoring supports behaviour change by drawing attention and resources toward the behaviour, bringing to

consciousness behaviour that people may otherwise prefer to ignore or reject and illuminating discrepancies between current behaviour and the goal [12,325,371,372].

The frequency and accuracy of the recording(s) are likely to mediate the effectiveness of self-monitoring, as a clear picture of the current position allows deviations from goals to be identified before a considerable, and potentially overwhelming, amount of corrective action becomes necessary [373]. Frequent self-monitoring has often been associated with improved weight management (e.g. [373,374]), even during periods associated with feasting [355]. Frequent self-monitoring of blood glucose levels have been found to result in improved glycaemic control for people with diabetes [375]. Regular reporting of alcohol consumption has been found to reduce consumption over the two-year period of an intervention [376].

Feedback allows the rate of progress toward a goal to be determined. Control Theory posits that when the rate of progress is below a self-set criterion, negative affect arises and increased effort is made toward the goal. When the rate of progress is above the criterion, positive affect arises and effort toward the current goal is reduced in order it be conserved or refocused elsewhere [133]. However, negative affect will only lead to increased effort when the goal is seen as attainable, feedback that suggests the goal is unattainable, or indicates that insufficient progress has been made, can result in goal abandonment [133–136]. Withdrawing effort and commitment from an unattainable goal may be an adaptive facet of self-regulation because it allows an individual to avoid failure experiences and the accompanying psychological distress [377]. Failing to meet an alcohol reduction goal can result in feelings of guilt and distress, which can lead to the failure of subsequent consumption goals [378].

Research has found that experimentally manipulating the type of feedback received about performance on a task can affect performance on subsequent tasks. For example, people with low

self-esteem were randomly given false success or failure feedback about their performance on a task; their performance on a subsequent task improved when they received success feedback and diminished when they received failure feedback [379]. Similarly, people with high self-consciousness were randomly given false success or failure feedback about performance on an intellectual task, those receiving failure feedback subsequently drank more alcohol than those given success feedback [380]. People given success feedback about their performance on a series of tasks subsequently chose to work for a valuable but contingent reward more often than those given failure feedback [381]. Taken together, these studies suggest that success feedback provided by an external source can increase self-regulatory capacities and improve task performance and persistence.

Meta-analyses that have examined the active ingredients in behaviour change interventions have regularly found self-monitoring to be an effective BCT. A meta-regression of BCTs in healthy eating and physical activity interventions found that self-monitoring explained the greatest amount of heterogeneity among studies [13]. A systematic review of weight loss interventions described self-monitoring as “the centrepiece of behavioural weight loss programs” (p1, [357]) and found a significant positive association between self-monitoring and weight loss across the 22 studies included in analysis [357]. A meta-analysis of alcohol reduction interventions found that self-monitoring was the BCT associated with the greatest effect size [281].

Feedback augments the effects of self-monitoring. A review of RCTs that evaluated the effect of self-monitoring blood glucose levels found that participants given regular feedback reduced their glycated haemoglobin by more than twice that of participants who self-monitored without feedback [382]. Participants were more likely to successfully lose weight (defined as weight loss of $\geq 5\%$ at six-month follow-up) if they were given feedback than if they were just asked to self-monitor without feedback [383]. Participants given feedback about their diet were found to adhere to self-monitoring more frequently than participants not given feedback, and to have significantly reduced their weight

at the end of the two-year follow-up (weight loss reported in the no feedback groups did not reach statistical significance) [384].

Self-monitoring appears to be more effective when combined with other BCTs that Control Theory predicts would act synergistically with it, i.e. goal setting, action planning, feedback and goal review. Weight loss interventions which used self-monitoring with at least one of the other BCTs consistent with Control Theory resulted in a pooled effect size of $d = 0.42$ (95% CI: 0.30 to 0.54), compared to the pooled effect size of $d = 0.26$ (95% CI: 0.21 to 0.30) for other interventions [13]. The inclusion of more Control Theory congruent BCTs was linearly associated ($\beta = 1.13$) with an increase in weight loss in complex interventions for obese adults [14]. A meta-analysis of the effect of self-monitoring on goal attainment found that interventions that included self-monitoring with feedback, goal setting and action planning produced larger effects than interventions not including that combination of BCTs [325].

Self-monitoring is a frequently used BCT in physical activity and healthy eating apps [295,385–387], medical adherence apps [308] and wearable activity monitors [388]. Self-monitoring was considered the BCT most likely to be effective in an alcohol reduction app by alcohol and behaviour change experts [16]. More than half the alcohol reduction apps available in the UK used the BCT of self-monitoring [Chapter 2]. Feedback is a commonly included BCT in alcohol face-to-face interventions [389] and DBCIs (e.g. [5–7,211,212,390]). A review of interventions that used motivational feedback as a core BCT found that 77% of the studies reported a significant reduction in drinking in the experimental group compared with the controls [391]. A meta-analysis of the effects of interventions that gave personalised feedback reported a pooled effect size of the interventions of $d = 0.22$ (95% CI: 0.16 to 0.29) [392]. A narrative synthesis of the treatment approaches used to prevent college student drinking identified eight studies which had used feedback as a comparator condition, five of which found reduced measures of consumption or alcohol related problems in the

feedback conditions relative to controls; two of the remaining three studies found improved outcomes in both groups [393]; differences between groups tended to no longer be significant at follow-up periods of three to six months, however. Motivational interviewing is a commonly used approach for alcohol reduction [394,395], and is more effective when feedback is provided. A study that sought to uncouple the effects of feedback from those of motivational interviewing found that motivational interviewing with feedback reduced alcohol consumption more effectively than motivational interviewing without feedback [350].

Feedback has been found effective whether delivered in-person or remotely via postal mail or the internet [391,393]. Written feedback has been found to be as effective as that given face-to-face for reducing alcohol and substance use [396].

In summary, the theoretical importance of self-monitoring and feedback for self-regulation, the evidence for their effectiveness in other health behaviour change domains and alcohol intervention modalities and the complementary relationship self-monitoring has with feedback, mean that self-monitoring in combination with feedback are suitable BCTs for evaluation in an alcohol reduction app.

4.2.2 How self-monitoring and feedback have been implemented in other alcohol DBCIs

An examination of the BCTs used in DBCIs to reduce excessive alcohol consumption found that 29% of the interventions (n = 12, of 42) used a self-monitoring BCT (self-monitoring of behaviour, self-monitoring of outcomes of behaviour and/or monitoring of emotional consequences). The same study found that 'Feedback on behaviour' was included in 86% of trials (n = 36) and 'Feedback on outcome(s) of behaviour' in 69% of trials (n = 29) [Chapter 3].

Nine of the interventions that included a self-monitoring BCT allowed for ongoing self-monitoring [178,279,330,335–338,397,398] the remaining three consisted of a single session, in which

participants were asked to reflect on previous levels of consumption and/or alcohol-related problems [347,350,399]. Of the interventions that allowed for ongoing self-monitoring, six were web-based [178,330,335–337,398], one was a stand-alone computer program [338], one was an app [279] and one required participants to print out and complete a form [397].

Feedback on behaviour consisted of feedback about the quantity and frequency of consumption. This was presented in the form of feedback about total consumption over a given period, average consumption per day/week/month, frequency of heavy drinking episodes, number of days when alcohol was consumed and/or average number of drinks consumed on typical drinking day (e.g. [346,397,400]). Feedback on outcomes of behaviour often consisted of feedback about the calories consumed from alcohol or amount of money spent on it (e.g. [349,401]). Other often-provided forms of feedback were about alcohol-related problems such as violence or unsafe sex, the risk status for dependency associated with current levels of consumption and the negative consequences that current levels of consumption might have to health, relationships with other people or work performance (e.g. [328,402]). Less common forms of feedback were about the familial risk for alcohol problems and risk of psychological problems, such as depression and anxiety (e.g. [21,403,404]). Biofeedback consisted of information about estimated peak or typical blood alcohol content levels (BAC, e.g. [279,328,350]). Information was sometimes provided about how long it takes a certain number of drinks to be metabolised [346], the legal consequences of different BAC levels [345], or what a moderate drinking BAC looks like [349]. Normative feedback consisted of feedback that compared a participant's levels of drinking with that of people their own age, gender or social group, or from people in the same university, area or country (e.g. [405,406]).

The self-monitoring procedure in the interventions accessible at time of publication asked participants to enter the number of standard drinks they had consumed that day or week [336,337]. There appeared to be no way of entering a drink's alcohol by volume (ABV), which would allow for

more accurate recording of the amount of ethanol consumed (Down Your Drink currently allows participants to enter the ABV of their drink, but it is unclear if this facility was available in the version of the web site evaluated [178]). Reminders did not appear to be frequently used; only one intervention reminded participants to complete a log of their drinking [336], the other nine either did not send reminders [330,338,347,397], or did not state if reminders were sent [178,279,335,337,407].

Feedback was presented in the form of graphs and/or text, usually related to a single period of consumption and was either neutral or negative in tone. Little feedback about progress was given; mostly because relatively few interventions allowed for ongoing self-monitoring, without which progress could not be measured. Feedback was sometimes compared against recommended guidelines for consumption [337,398,408], but rarely against participant-set goals.

4.2.3 How apps might improve self-monitoring and feedback

Apps may be able to increase the frequency and temporal proximity of self-monitoring because they are contained within a device people typically keep close at hand and use hundreds of times each day [217]. Frequency of recordings can be promoted with the creation of user-friendly data entry mechanisms. Prompts and alerts reduce the need for self-monitoring to be remembered and, should they be carefully scheduled or triggered, may make it easier for the outcomes of drinking behaviour to be identified and recorded.

The immediate and ongoing feedback that apps can provide may promote prolonged goal striving. Immediate feedback has been found more effective than delayed feedback [325], perhaps because immediate feedback allows discrepancies between one's current position and the goal to be identified before an overwhelming amount of corrective action becomes necessary. Feedback indicating sufficient progress has been made toward a goal may increase self-efficacy [131,132],

enhance self-regulatory capacities and improve task performance and persistence [379–381]. Rule-based logic can be used to detect and respond to underperformance, desired progress, or a surfeit of progress toward a goal. A rule-based feedback approach for the app to be evaluated is described in section 6.3.10.3.2, below.

4.3 Action plans

4.3.1 Theoretical basis and evidence for the effectiveness of action planning

After a goal has been established and one's current position in relation to a goal ascertained, an action plan determines how discrepancies between that position and the goal can be addressed [12]. Intentions only account for about 28% of the variance in future behaviour [409] and greatly increasing intention strength does not result in a correspondingly large increase in goal attainment [410]. The intention-behaviour gap may be mediated by action planning [411], described in the BCTTv1 taxonomy as "Prompt detailed planning of performance of the behaviour" [8]. Action plans appear particularly effective in the form of implementation intentions, which specify where, when and how a behaviour will be performed in the service of goal attainment [112].

An implementation intention is a pre-specified behaviour scheduled to take place when a situation expected to present challenges or opportunities for goal attainment is encountered. Implementation intentions consist of an 'if' - the cue to act triggered by a situation or event; and a 'then' - the behaviour. For example "If I've had two drinks in the pub after work and I'm offered a third, then I'll say 'no thank you, I've got a busy day tomorrow'".

A meta-analysis of 94 trials found that implementation intentions had a medium-to-large positive effect on goal attainment across a wide variety of behaviours ($d = 0.65$; 95% CI: 0.60 to 0.70) [113]. A considerable part of their effectiveness appears to arise because the behaviour is automatically triggered whenever the cue is encountered. In their meta-analysis, Gollwitzer & Sheeran (2006)

found that implementation intentions greatly increased the detection, discrimination, accessibility of, and attention paid to, cues [113]. The automaticity of cue-triggered behaviour reduced cognitive load, overcame conscious barriers to goal initiation, ensured focus remained on goal attainment and retained effort for subsequent goal striving [113].

To be effective, implementation intentions need to be carefully detailed and rehearsed in advance; this helps the behaviour be performed without thinking when the situation is encountered. The situation that cues the behaviour should be unambiguous in order for it be clearly recognised, and the behaviour that results should be both appropriate for the situation and also lead to goal attainment. Cues can relate to internal states or external situations, be associated with opportunities to act or obstacles to overcome and can trigger behaviours that lead to goal attainment or suppress the responses that hinder it [113].

The automaticity with which implementation intentions are enacted and the low toll they take on cognitive load may make them particularly suitable for cue-reactive behaviours such as alcohol consumption [68,114]. Alcohol consumption increases the challenges for self-regulation as effortful cognitive processing becomes more difficult and attention is focussed on meeting immediate needs rather than long-term goals [48,362]. Automatic processes that circumvent conscious self-regulation may be effective in reducing alcohol consumption [412].

Implementation intentions have been found to reduce alcohol consumption in face-to-face interventions [114,413,414]. However, they are infrequently used in DBCIs [Chapter 3] and no evaluation of their effectiveness as a stand-alone BCT in this modality appears to have been conducted. In addition, most trials of implementation intentions have been conducted in the lab and amongst university students; more evidence is needed for their effectiveness in the field and amongst the general population [113].

4.3.2 How action planning has been implemented in other alcohol DBCIs

Action planning was used in 13 of the trials (32%) included in a Cochrane review of alcohol DBCIs [Chapter 3]. Most interventions recommended that participants set action plans to help achieve drinking goals and also to deal with situations in which they might be tempted to drink excessively (e.g. [328,329]), though some focussed only on dealing with difficult situations (e.g. [178,339]) or achieving goals (e.g. [415]).

Some interventions merely advised an action plan be set (e.g. [339]), others facilitated the process by walking participants through the process step-by-step (e.g. [328]) and at least one intervention provided participants with examples of action plans [337]. A recommendation to set implementation intentions was only included in one trial [336].

4.3.3 How apps might improve action planning

Apps may be able to improve the effectiveness of action planning in at least three ways. First, the tendency of people to keep their smartphone close at hand [217] allows action plans to be regularly or spontaneously revisited, rehearsed and updated, which may strengthen the connection between a cue and its response. Secondly, apps could enable reminders to be set so that action plans are displayed at times when other activities make them more difficult to recall, such as in the late evening at a party². Thirdly, location sensing may in the future be accurate enough to detect when an individual has entered an environment expected to cause challenges for executing or remembering an action plan, such as being in a bar, and display relevant plans at that point.

² Unfortunately budget limitations prevented the implementation of this feature in the app to be evaluated

4.4 Goal setting

4.4.1 Theoretical basis and evidence for the effectiveness of goal setting

Goals have been found to affect performance in four ways. 1) Goals focus attention and effort on goal attainment; 2) have an energising effect which can lead to the investment of greater effort; 3) increase persistence and prolong effort; and 4) bring to awareness skills needed to complete the task or motivate learning of new skills necessary for its completion [128].

4.4.2 Goal difficulty and specificity

Goals particularly assist performance and persistence when they are both appropriately difficult and specific [127]. Easy goals do not require the application of great effort [128]. Vague goals such as 'do-your-best' allow for a wide range of acceptable performance and lack a reference point essential for measuring achievement or progress [129]. A meta-analysis of more than 100 studies published between 1966 and 1984 found that goal difficulty and specificity were strongly related to task performance across a variety of tasks and settings [416]. Provided the individual believes they have the ability to attain the goal, is committed to the goal and does not have conflicting goals, a positive, linear relationship has been found between goal difficulty and task performance [128]. Self-set or participatively set goals appear to be equally as effective as assigned goals when goal difficulty is held constant [127,128].

4.4.3 Goal proximity

Proximal goals, goals attainable in the near future, can increase motivation and persistence more effectively than distal, i.e. long-term or far off, goals because they provide clearer feedback about progress [130,131]. Feedback about progress toward proximal goals and the sense of achievement found in reaching them can increase self-efficacy, improve satisfaction with performance and positively affect future task persistence [131,132].

Children who set a proximal goal for self-directed learning increased their ability in and self-efficacy for a subject they had previously struggled with, compared to children who set a distal goal or no goal at all [417]. Young adults who had been given a proximal and a distal goal for making toys earned more money and increased their self-efficacy more than those only given a distal goal or a 'do your best goal' [131]. People can set proximal goals even when assigned a distal goal; a majority of the participants assigned a distal weight loss goal spontaneously set themselves proximal goals, and these participants lost more weight than the few who retained only the distal goal [418].

4.4.4 How goal setting has been implemented in other alcohol DBCIs

Twelve interventions (29%) in a Cochrane review of alcohol DBCIs used the BCT of 'Goal setting (behaviour)' and five (12%) used the BCT of 'Goal setting (outcome)' [Chapter 3]. Interventions which used 'Goal setting (behaviour)' most usually suggested setting a goal of number of units or drinks per week; a small number suggested setting a goal for number of alcohol-free days a week (e.g. [337]). The type of outcome goal was often unclear.

Some interventions simply suggested participants set a goal (e.g. [397]), others allowed participants to set a goal on the web site (e.g. [336]). Interventions used government guidelines for consumption as a goal or let participants set their own goals. Only three interventions allowed participants to review progress against their goals [178,336,337], none of which appeared to have suggested changing goals that were too difficult or too easy.

4.4.5 Why goal setting was not selected for evaluation

Goal setting is an essential BCT to include if the effectiveness of self-monitoring, feedback and action planning are to be evaluated. A goal determines the behaviour to be monitored, the feedback to be attended to and the desired end state to be planned for.

The purpose of this version of the app is to determine which BCTs should be included in a subsequent version of the app that will itself be evaluated in a randomised control trial against a minimally active control (described in more detail in Chapter 6). The evidence for goal setting as a standalone BCT, its importance to the other BCTs that will be evaluated in this trial and as such, its expected inclusion in the subsequent version of the app, meant that goal setting was not selected for evaluation. All participants were, therefore, given the BCT of goal setting.

4.5 Conclusion and next steps

This chapter drew on findings from previous chapters, and wider evidence and theory, to provide a rationale for the selection of BCTs to be evaluated in the app, called *Drink Less*. Goal setting was judged to be requisite and so was included for all evaluation participants. Self-monitoring combined with feedback, and action planning were judged as high priority for evaluation. BCTs for evaluation were detailed for use in two conditions: an 'enhanced' condition containing enhanced elements of the BCT for the experimental group and a 'minimal' condition for the control group. The way these BCTs were implemented in the app is described in Chapter 6.

A development company was selected to build the app and a first version was launched in May 2015 in the UK version of the Apple App Store. The high rates of attrition commonly experienced with DBCIs [181] mean that it is important to change the design of apps on the basis of user feedback in terms of ease and enjoyment of use. The following chapter describes the usability studies that were undertaken in order to formally gather user suggestions for improvement.

5 Understanding the user experience of an app to help people reduce their alcohol consumption.

5.1 Abstract

5.1.1 Background

Interventions delivered by smartphone apps have the potential to help drinkers reduce their consumption of alcohol. To optimise engagement and reduce the high rates of attrition associated with the use of digital interventions it is necessary to ensure that an app's design and functionality is appropriate for its intended purposes and target population.

5.1.2 Aims

To understand the user experience of an app to help people reduce their alcohol consumption.

5.1.3 Method

The app, *Drink Less*, contains a core module focusing on goal setting, supplemented by five additional modules: Self-monitoring and Feedback, Action Planning, Cognitive Bias Re-training, Normative Feedback and Identity Change. In order to understand the usability of the app two studies were conducted, a 'think aloud' study performed with people using the app for the first time and a semi-structured interview study performed after users had had access to the app for at least 2 weeks. A thematic analysis of the 'think aloud' and interview transcripts was conducted by one coder and verified by a second.

5.1.4 Results

Twenty-four participants, half of whom were women and half from disadvantaged groups, took part in the two studies. Three main themes identified in the data were: 'Feeling lost and unsure of what

to do next'; 'Make the app easy to use'; and 'Make the app beneficial and rewarding to use'. These themes reflected participants' need for: 1) guidance, particularly when first using the app or when entering data; 2) the data entry process to be simple and the navigation intuitive; 3) neither the amount of text nor range of options to be overwhelming; 4) the app to reward them for effort and progress; and 5) it to be clear how the app could help alcohol reduction goals be reached.

5.1.5 Conclusion

First time and experienced users want an alcohol reduction app to be easy, rewarding and beneficial to use. An easy-to-use app would reduce user burden, offer ongoing help and be aesthetically pleasing. A rewarding and beneficial app would provide positive reinforcement, give feedback about progress and demonstrate credibility. Users need help when first using the app and they need a compelling reason to continue using it.

5.2 Introduction

The usability of a technology is a key factor in its adoption [419], particularly for smartphones, whose small screens and keyboards, and wide range of settings in which they are used, present particular usability challenges [420–424]. Smartphone apps are quickly discarded; 20% are used only once [425] and up to 75% are deleted within three weeks [426]. Digital behaviour change interventions (DBCI) experience similarly high rates of attrition [181,427]. To optimise engagement with an app-delivered DBCI it is necessary to ensure that its design and functionality is appropriate for its intended purpose and target population [189].

Traditional user testing has tended to focus on the utilitarian or hedonic qualities of a technology [428–431], such as how fun or absorbing a technology is to use [431–434]. However, this approach is not entirely appropriate for DBCIs, where the goal is not necessarily to create technology that is fun

or absorbing but rather, technology that encourages sufficient engagement with the intervention for the intended outcomes to be achieved [182].

Engagement with an intervention can be understood by adopting a person-based approach to DBCI development. The person-based approach melds traditional user testing with an approach that seeks to understand not just the hedonic or utilitarian qualities of a technology, but also the suitability of the component behaviour change techniques (BCTs) and the challenges faced or anticipated in adhering to them [189]. In this way, acceptable and feasible BCTs can be identified and improved, with impractical or intrusive BCTs replaced [189].

Usability studies of DBCIs commonly use the ‘think aloud’ method to capture experiences of using technology [435,436]. The method encourages users to verbalise in running commentary what they are looking at, thinking about, doing and feeling as they engage with the technology spontaneously or in response to researcher-directed tasks [437]. ‘Think aloud’ studies can be performed with small numbers of participants [438,439], who provide information about difficulties encountered using the technology and the things that are liked, whether the BCTs appear acceptable or impractical, and what users think of the technology’s graphic design, navigation and functionality.

‘Think aloud’ studies are a valuable tool for user testing but are typically not conducted in real-world settings. Smartphones are often used in contexts that present specific challenges to usability, e.g. when walking or on public transport, in noisy or distracting environments, and for brief periods of time [420,424]. Furthermore, whilst it is useful to conduct studies that evaluate a user’s first impressions of an app, DBCIs often require repeated use in order to influence behaviour. The extent to which a user returns spontaneously to the intervention, the degree to which prompts and notifications are intrusive, the suitability of prolonged use of the BCTs suggested and the ease of interaction in different contexts of use can better be answered after users have engaged with the

app for a period of time. Conducting usability studies after users have had the opportunity to use the app repeatedly and in natural settings is therefore recommended [189,424,440].

The studies reported here assessed the usability of a new app in terms of both immediate impression and experience of use. The first study aimed to assess initial impressions and the ease of using features, entering data and navigating to specific items of content by a 'think aloud' study performed with users encountering the app for the first time. The second study aimed to understand the lived experience of the app by a semi-structured interview study performed with users who have had access to the app for at least two weeks. Both studies adopted a person-based approach in order to determine whether the BCTs used in the intervention are acceptable, easy to use and feasible and if not, what suggestions for improvement can be gained.

The app to be assessed, *Drink Less*, is intended to help harmful and hazardous drinkers reduce their consumption of alcohol. Users have access to modules that allow them to set goals, create action plans, monitor their drinking and engage in a range of tasks designed to help them reframe their responses toward alcohol. The app provides feedback on consumption and how this relates to the goals set. Additional information is provided on tips to reduce drinking, harms of drinking and the importance of setting appropriate goals. Many of these are BCTs commonly used in alcohol reduction apps [Chapter 2] and some BCTs, self-monitoring, feedback and goal setting for example, are commonly used in physical activity, weight loss and smoking cessation apps [238,245,283]. Understanding how these techniques can be refined to better meet user needs could have application beyond the specific alcohol reduction app tested.

Concern has been expressed that DBCIs may exacerbate health inequalities [190], as people with greater social disadvantage tend to make less use of primary healthcare services [197] and often have poorer online literacy [441]. There is evidence that including disadvantaged groups in the

design and usability testing of new interventions produces DBCIs more appealing to those groups [177]. We therefore ensured that at least half the participants for each study were from disadvantaged groups.

The aim of this study is to explore user views toward an app to help people reduce their consumption of alcohol. Findings will not only inform the refinement of the app but may also inform intervention developers about how an app's BCTs and design can be altered to improve the user experience, reduce attrition and increase engagement.

5.3 Study 1: Investigation of first impressions: 'Think aloud'

5.3.1 Methods

5.3.1.1 Study sample

Participants were recruited from a convenience sample of members of staff at a London university, their family and friends, as well as subscribers to an alcohol-reduction mailing list. Inclusion criteria were people interested in reducing their alcohol consumption and who had an AUDIT-C (Alcohol Use Disorder Identification Test – Consumption) score greater or equal to 5, which reflects potentially harmful levels of drinking [442]. A purposeful sampling approach was taken in order to ensure the views of disadvantaged groups were gathered; half the participants in both studies had no post-16 educational qualifications, were unemployed, or were employed in a routine/manual occupation. Participants were given £20 in compensation for their time.

Of the 12 participants in the 'think aloud' study 50% were female and 50% were from disadvantaged groups. Their mean age was 42 years and the mean interview length was 59 minutes.

5.3.1.2 Procedure

Participants were set a series of tasks, for example: complete the registration process; add drinks to the drinking diary; set goals; play the game, browse the app. They were asked to verbalise what they thinking about, looking at, doing and feeling throughout the process. After the 'think aloud' study had finished, users were asked if they have any suggestions for how the app could be improved or any additional comments they wished to make. A full set of interview topics can be found in Appendix 8.9.

Participants chose the date and time of the interview, and were reassured that their responses would be anonymised and stored securely and that they had a right to withdraw any time. Participants gave written informed consent before the study commenced. All interviews were carried out by the first author.

Ethical approval was obtained from the Clinical, Educational, and Health Psychology Research Department's Ethics Committee at University College London (UCL), Reference: CEHP/2013/50, 1st May 2015.

5.3.1.3 Analysis

Interviews were audio recorded, transcribed verbatim and analysed with thematic analysis, a method commonly used in qualitative research for "identifying, analysing and reporting patterns (themes) within data" (p79 [443]). The method allows for the similarities, differences and key features of a large body of data to be summarised and for its predominant themes to be identified. Thematic analysis is suitable for mixed-methods qualitative studies [444] and has been used to analyse usability studies of internet interventions and smartphone apps [445–447].

Transcripts were read multiple times in order their content be familiarised. Notes taken during these readings were used to generate an initial set of themes. Extracts were coded against these initial

themes in an iterative process that led to new themes being identified or existing themes renamed in ways that more accurately captured the essence of the data. Transcripts were read multiple times during the coding process and then again once coded had finished in order to ensure that all extracts relevant to the research question of understanding user views toward an alcohol reduction app had been identified and that extracts had been coded against the most appropriate theme. Themes were grouped into themes and sub-themes and hierarchically organised to reflect their prevalence in the data. Quotes that accurately illustrated the themes were identified. Quotes were edited to improve readability without changing the essence of the quote (unedited transcripts are available on request). To verify coding accuracy a second coder independently coded 10% of the extracts, chosen at random, against the finalised set of themes. Percentage agreements were 84% agreement for the first study and 90% agreement for the second.

5.3.2 Results

Three themes and 12 sub-themes were identified, as summarised below.

5.3.2.1 'Feeling lost and unsure of what to do next'

Participants using the app for the first time frequently expressed confusion about how to use the app and how to navigate through it. Confusion was most pronounced when participants first started using the app after completing the registration process.

5.3.2.1.1 'Help me when first using the app'

Registration is an expected, familiar and uncomplicated process which participants worked through sequentially. When complete, participants were automatically taken to their dashboard, a screen that contained an empty graph and a number of links to other modules in the app. The abrupt appearance of this screen, its lack of visual concordance with the screens that preceded it, and the number of links available, confused participants, who were unsure if registration had finished and on

which link they should start with. This created a poor first impression, with almost all participants expressing a desire for a stepped guide to walk them through their initial use of the app.

I want something to tell me “Do number 1 first, then number 2. When you’ve done this go here” so I don’t have to think too much about it. Once I’ve got it up and running I’m fine.

[P1, Female]

I got confused when I’d finished logging-in. There was nowhere to say “Welcome, you’ve registered”. There was nothing that told me I’d finished registering. Which was annoying.

[P12, Male]

5.3.2.1.2 ‘How do I get to where I need to be?’

Participants often felt disorientated within the app and were unsure how to navigate through it.

They were not comfortable exploring the app and clicking links at will, often because they thought there were things they should be doing to set-up the app but weren’t clear what these things were.

When unsure where to go next, participants tried to retrace their steps and became frustrated when there was no easy or obvious way for them to do so.

In the absence of guidance, some participants worked logically through the app, moving left-to-right through the horizontal tab bar at the bottom of the app and top to bottom on the screen. If the order of items didn’t make sense, if links took participants to an unexpected place, or when the navigation was inconsistent (on some screens the horizontal tab bar was hidden) participants felt confused and annoyed.

Okay, I’ve done my goals. But I don’t know what I do next. Do I press Games, do I press Dashboard again?

[P5, Female]

Okay, so now the mist has gone up again, because it's not telling me where to go next. There's no Exit button, there's nothing.

[P4, Male]

5.3.2.2 'Make the app easy to use'

Participants wanted a visually appealing app that helped them learn how to use it and did not overwhelm them with choice.

5.3.2.2.1 'Do not make me work'

Participants wanted an app whose use required minimal effort. Some said they may be willing to invest more time than they would with other apps because this app was designed to help them.

Others said they would stop using the app if it was too difficult, despite believing that their drinking was an issue they needed to address. Participants had formed expectations about how elements of the app should work based on their experience of using other apps, and were disappointed when the app failed to meet these expectations (for example, users expected a calendar to appear when a date was tapped). Elements that were straightforward and intuitive, such as adding drinks were praised.

What I'm thinking is, this better be easy, because otherwise I'm probably not going to do it. If there are too many obstacles in the way I won't. Even though I know I need to do this, I probably won't.

[P1, Female]

There was frustration but I wouldn't just bin it because I know it's an app that is trying to help me. It probably needs a little bit more time, and I'd be willing to do that.

[P7, Male]

5.3.2.2.2 'Provide clear guidance throughout'

Guidance was sought when using many other areas of the app, particularly when using modules that required input but came without instruction, for example setting goals, adding drinks, creating action plans, or using the identity section. Participants often hesitated before entering information, partly because they were unsure what was required of them; partly because they felt the accuracy of their entries was important and did not know if mistakes could be corrected; and partly because they wanted more help from the app about what entries were appropriate (for example some participants wanted to know whether the goals they had set were realistic). Participants were frustrated when the app prevented them from completing tasks, such as saving an action plan, without clear indication about what they were doing wrong. Instructions provided on how to play the game were thought overly complex and difficult to follow.

So I guess that's the kind of information I was crying out for when I was doing the goals. How do I set good goals? Is [spending a maximum of] £40 unrealistic at this stage?

[P7, Male]

What's annoying is that I'm really happy that I opened up and put my real reasons, but now I can't save it because you can't save unless you put an action in. But if I knew how to take the action I wouldn't be using the app. Now I'm getting frustrated. Tell me! I want it to tell me.

[P1, Female]

5.3.2.2.3 'Make it visually appealing'

The visual appearance of the app played an important role in its perceived ease of use. Visually unattractive screens were off-putting to participants, who often expressed a desire for more graphic ways of presenting information. Participants found icons more pleasing and more memorable than text links and requested they be used more frequently. Some of the graphs did not make intuitive sense at first and participants suggested better ways of displaying these data. Screens that

were clean and simple were praised and held in contrast to those that were busy and aesthetically dull. Many participants appreciated the consistent design of the app but the green colour used throughout was not universally liked.

The drink panel was easy to use because it was really visual.

[P8, Female]

I'd probably like to see a page with icons on rather than text. Because it always feels a bit more serious when you've got the text.

[P11, Male]

5.3.2.2.4 'Do not overwhelm me'

The range of modules available was overwhelming for some participants who wanted a leaner and more condensed app. Screens full of text, or text that appeared complex to read and understand, were off-putting to participants who wanted to keep their reading to a minimum.

First of all, this is a wall of text so it's not that inviting

[P3, Female]

There seems to be too much on there, I think I would find it off-putting. If I was going to use something it needs to be quick and straightforward. There seems to be too much, too many pages of things to do, which I know that I probably wouldn't end up doing.

[P10, Female]

5.3.2.2.5 'Blame myself, not the app, if it's too hard to use'

When a minority of participants did not understand what was asked of them, or did not know how to use the technology, their tendency was to blame themselves and their shortcomings rather than the app for its poor design.

I'm sure my six year-old nephew would be able to do this by now

[P2, Female]

I'm always my own worst critic. Realising I can't do this makes me think that I'm at fault, not the app.

[P9, Male]

5.3.2.3 'Make the app beneficial and rewarding to use'

Participants didn't understand how some of the modules could help them reduce their consumption of alcohol and wanted to know why they should trust the information provided. They sought messages of congratulations and encouragement for actions they had taken and thought the app unrewarding to use when its tone was judgemental or formal. Instead, participants wanted the app to use language that was more friendly and funny.

5.3.2.3.1 'How will it help me?'

Participants thought the app potentially useful overall, but did not understand the benefit of using some of the individual modules, especially the Cognitive Bias Re-training game and the Identity Change section, where the relationship between use of the module and reducing alcohol consumption was unclear. The effectiveness of the game was particularly doubted; many participants were unsure of its purpose, or thought it simplistic and unlikely to help them drink less. Participants were unlikely to use modules they could see no obvious benefit to and expressed a desire for more information about why a module had been included and how it was theorised to work.

You have finished the game. What was the point of that? Seriously. Really, what was the point of that? Am I missing something? No, I'm not impressed, I don't know what it was, I don't know why I've just done that.

[P12, Male]

Actually I think more explanation about the psychology around why this might help as a training game would be really useful.

[P8, Female]

5.3.2.3.2 'Reward me for my achievements'

Participants were often unsure if they had successfully completed a task and expressed a desire for visual or audible confirmation at the point of task completion, for example when a goal had been set. Participants often requested more positive reinforcement from the app and were appreciative when it congratulated them for actions. The sound that was played when participants recorded a drink was particularly appreciated as it was felt to be a reward for their achievements and helped establish a positive relationship with the app.

There's nothing saying "Right, thank you for that. Next option".

[P4, Male]

When it moves on to the next thing I feel great, I've achieved something, I've filled something in correctly. I like that. And a nice little noise which made me think, Oh, I'm not an idiot.

[P9, Male]

5.3.2.3.3 'Do not be judgemental'

Some participants felt the app delivered information in a straightforward and non-judgemental tone. Others took the opposite view and considered the information to be judgemental or preaching; a tone they strongly disliked and which made use of the app feel dissatisfying. The feeling of being judged was often expressed when participants received feedback about their levels of drinking which contrasted with their perception of their consumption, for example when they received their AUDIT (Alcohol Use Disorder Identification Test) score or were given normative feedback (where participants were shown how their drinking compares to other people in the UK). Participants who greatly underestimated their levels of drinking compared to others found the comparison shocking

and thought the app was placing them in a category of drinkers to which they felt they did not belong. It was notable that once participants saw one module of the app as judgemental they tended to see other modules as judgemental too.

It didn't make me feel judged. Aside from one or two words here and there it was understanding. I think the tone is understanding.

[P8, Female]

Well according to this I'm doing something wrong

[P4, Male]

5.3.2.3.4 'Be friendly and funny'

Participants disliked when text was perceived as overly formal or impersonal. They wanted the app to have a friendly, humorous, tongue-in-cheek and light-hearted tone of voice, despite the serious nature of the subject. A too formal tone was perceived as judgemental and off-putting. Participants appreciated parts of the app that were more light-hearted and said it helped them feel relaxed and made them want to engage more with the app.

The language is a bit stale. It could be more personal.

[P8, Female]

I suppose [informal language] is a slightly cheeky, jokey, way in. Of maybe making me feel a little bit more relaxed, maybe not feeling too conscious about giving all my drinking secrets away.

[P1, Female]

5.3.2.3.5 'Tell me I can trust the app'

The credibility of the app and the information delivered by it was an issue for a number of participants, particularly those who felt their normative feedback had judged them harshly and who then expressed a distrust of data about other people's drinking. Participants found that credibility

was established by use of the UCL logo on the first screen they saw after installing the app and by referencing of studies within the app. A number of participants said that the academic nature of the app and the fact that their data would be part of a study, increased the trustworthiness of the information and their positive views toward the app.

I don't believe that one iota. Less than a pint a day is 85% more than people in Great Britain drink. I don't believe that for a moment. Either other people are lying, which I assume they might with something like this, or it's skewed to scare me.

[P9, Male]

I think the UCL thing is quite important, that it is actually coming from academics. One of the things I really liked is when you go into the information and it shows you the research, that gives it some gravitas. I think that gives the app a lot more credibility.

[P5, Female]

5.4 Study 2: Investigation of the experience of app use: Semi-structured interviews

5.4.1 Study sample

Participants were recruited from users who had downloaded the app from the iTunes Store and volunteered their email address when completing the app's registration process. Inclusion criteria were the same as for Study 1, with the additional requirement that participants need to have downloaded the app at least two weeks prior to the interview taking place. A purposeful sampling approach enabled the views of disadvantaged groups to be gathered; half the participants were required to have no post-16 educational qualifications, or be unemployed, or be employed in a routine/manual occupation. Participants were given £20 in compensation for their time.

Of the 12 participants in the semi-structured interview study, 50% were women and 50% were from disadvantaged groups. Their mean age was 40 years.

5.4.2 Procedure

Participants were asked a series of semi-structured interview questions with a mean interview length of 33 minutes. Topics included: how they found the registration process, what their first impressions of the app were, how easy or difficult they found the app to use, whether they had any suggestions for how it could be improved or any additional comments they wished to make. A question was added in response to feedback from the first study. A number of users in the first study said they thought normative feedback about their drinking, which compared their drinking to other people in the UK, was not credible. In order to determine the extent to which this view was shared by people in the second study, participants were asked specifically to recall what their response was to the normative feedback. A full set of interview topics is in Appendix 8.9.

As with Study 1, participants chose the date and time of the interview, and were reassured that their responses would be anonymised and stored securely and that they had a right to withdraw any time. Participants gave written informed consent before the study commenced. All interviews were carried out by the first author and were audio recorded.

Ethical approval was obtained from the Clinical, Educational, and Health Psychology Research Department's Ethics Committee at UCL, Reference: CEHP/2013/50, 1st May 2015.

5.4.3 Analysis

Data were analysed using the same procedure as described for Study 1.

5.4.4 Results

The themes identified were broadly similar to those identified in the first study. However, the theme most prominent in the first study: 'Feeling 'lost' and unsure what to do next', was not identified in the second study. The two other themes from the first study: 'Make the app beneficial and rewarding to use' and 'Make it easy to use', were also predominant in the second study albeit with some different subthemes emerging.

5.4.4.1 'Make the app beneficial and rewarding to use'

As with the first study, participants wanted an app that engaged them and provided clear reasons to continue using it. However, this study revealed that for many participants the engaging elements were either missing or not apparent. Participants felt dissuaded from using the app when it adopted a judgemental tone of voice and wanted to know that the time and emotional investment they were making would be worthwhile.

5.4.4.1.1 'How will it continue to help me?'

Participants thought there was little within the app that would encourage repeated use and either never used, or had stopped using, modules they thought offered no benefit. As with the first study, this was particularly true of the Cognitive Bias Re-training game and the Identity Change modules, where it was unclear how the module could help reduce alcohol consumption. The Self-monitoring and Feedback module was thought to have most benefit, and a number of participants used the app for this feature alone, although some said they'd prefer to use an app like MyFitnessPal which was considered easier to use and allowed them to self-monitor their food intake as well as their alcohol consumption.

I think that's where it let itself down for me. Once I'd played with it, once I tried the game, done the identity and whatnot, there wasn't much else there for me.

[P4, Female]

So in the end I reverted back to one app. It may not necessarily provide something I want, it was just a lot more convenient. I drink a wide variety of drinks and I don't necessarily always know the content. And with MyFitnessPal you can just scan the barcode.

[P10, Male]

5.4.4.1.2 'Reward me for my achievements'

Participants appreciated positive visual and audible confirmations of their actions and achievements. They liked the sound played after a drink has been entered, the green tick that appeared when an alcohol-free day has been recorded and the green lines under the calendar that show periods of abstinence. Many participants asked for more encouragement and positive reinforcement in the form of badges or smiley faces to indicate periods of success, and supportive messages to encourage drinking reduction.

Then when you say 'drink free day' the app goes 'Congratulations!' and I feel great.

[P6, Female]

I know this sounds really pathetic but if you could earn badges for your non-alcoholic days, that might make people a bit more focussed on actually not drinking because they know they're going to earn points.

[P4, Female]

5.4.4.1.3 'Update me on how I am doing'

Participants wanted to receive feedback about their drinking and how it was changing over time. However, they often could not find this feedback, a situation they found frustrating and demotivating. Some participants had stopped entering data into parts of the app because without feedback, entering data was an unrewarding task. There were requests to make the feedback more prominent and the app was compared negatively with apps where feedback was easier to find.

Participants who managed to locate the feedback appreciated it, though they asked for more encouraging and positive messages.

But one thing that's a bit strange is you can set goals but there's never any feedback about whether you've made it or not.

[P6, Female]

I couldn't find any graph that's reflected the mood so therefore I didn't see the point of having to fill that part out and I stopped filling it out

[P7, Male]

5.4.4.1.4 'Do not be judgemental'

As with the first study, some participants saw the app as an impartial tool that did not make judgements about their drinking. Others perceived the app's agenda was to get them to stop drinking, believed some of the AUDIT questions were overly personal, felt guilty if they had not completed the daily tasks set by the app and saw the language used as sometimes patronising. Participants also worried about other people judging them and wanted to keep their use of the app private. They worried that the daily prompt to complete their drinking diary might be seen by colleagues or friends and were concerned that people such as their boss might gain access to their drinking data.

"You should drink less" was quite abrasive to me but potentially that's the objective if you are trying to get people to drink less.

[P10, Male]

I don't think it's made me feel guilty, I think it's made me feel very conscious of what I'm doing.

[P2, Female]

5.4.4.1.5 'Tell me I can trust the app'

There were mixed views about the credibility of the normative feedback information, which compared a participant's drinking to other people in the UK. Some participants found the feedback untrustworthy and thought other people must have underreported how much alcohol they consume. Others valued the comparison as it shocked them into action. In general, the normative feedback information was more trusted than in the first study. However, as participants for this study had searched for and downloaded an alcohol reduction app, it is likely they felt their drinking was problematic and may not have been as surprised to learn it was comparatively high to other people in the UK. Some participants liked that the app was linked to an academic study, appreciated the references that were included and thought more information about the reliability of the information would further support the credibility of the app and its modules.

I didn't really believe it either. I thought 'Wow other people must lie' because it said I drank more than 95% of the female population and I was thinking 'There's no way that's true'.

[P6, Female]

The reason [for choosing the app] was that it was linked to an academic study, it had people behind it who were identifiable, it had some kind of purpose which was bigger than just the app itself. That was the probably the strongest attraction I had to it.

[P1, Male]

5.4.4.2 'Make the app easy to use'

As with the first study, participants wanted a visually appealing app that made minimal demands on them, and provided guidance about how to use the modules.

5.4.4.2.1 'Do not make me work'

Participants in the second study tended to report that the app was easy to use. This was particularly true for the self-monitoring and goals modules, both of which were said to be simple and straightforward, in part because they did not require a great deal of typing. Participants encountered few difficulties with the registration process, some even said they appreciated its comprehensiveness as they felt the app needed to ask a lot of questions in order to be able to help. Participants were disappointed when their expectations about how the app would work, expectations formed from using other apps, were not realised. Modules that were new to participants, such as Action Planning and Cognitive Bias Re-training, were not intuitive and a bug which caused the Mood Diary to record drinks for the wrong day was seen as annoying.

[The app] was quite simple and sleek and straightforward. The worst apps are things that make it too complicated or take a long time to fill in.

[P3, Female]

When you enter a drink it's very easy to vary and be precise. For example, say you've got beer you've got variations on alcohol content, variations in size. It's very flexible that is, so you can be accurate.

[P1, Male]

5.4.4.2.2 'Provide clear guidance throughout'

Participants in the second study reported much less need for guidance on how to use the app. However, confusion remained about a number of modules where input was required but instruction was lacking. Participants wanted more examples and clearer guidance in order to resolve their uncertainty about what constituted an effective action plan or a realistic goal. Instructions about how to play the game were considered unclear and the game itself not self-explanatory. Participants also requested guidance on how to get the most from the app, for example they wanted the app to recommend the Mood Diary be completed at the same time each day in order to make the

comparisons more accurate. Some of the graphs were seen as unintuitive and advice on how to delete drinks or enter drinks for different days was requested.

I think it was quite hard to begin with, not in terms of the app usage itself but creating goals. I found that quite tricky. Maybe if there had been some suggestions about what goals I should have been setting that would have been really useful.

[P8, Female]

I think really I need to play with it more. It's not self-explanatory to me how you actually fill in some of the bits.

[P4, Female]

5.4.4.2.3 'Make it visually appealing'

The visual appeal of the app was positively commented upon by many participants in the second study who thought the app looked friendly, trustworthy and non-intrusive. The simple, clean and clear design, use of green as the main colour, the calendar and the app icon were all liked by participants. Some found the app little dull to view and wanted more imagery, but these were fewer in number than in the first study.

I think generally it's very well designed. It's clear, it's useful. I like the design. I quite like the way it's all mapped out, I think it's very good.

[P7, Male]

I liked the way it looked. It felt quite friendly. Not intrusive and not scary I suppose. The colours I liked. They weren't judgemental colours, there wasn't a lot of red, so it was quite a safe feeling in terms of the colours that were used.

[P8, Female]

5.5 Discussion

Participants using an alcohol reduction app for the first time and participants who had been using the app for at least two weeks wanted an app that was both easy and rewarding to use. Whilst these findings are perhaps unsurprising, few people are likely to want an app to be difficult or unrewarding, the contribution this study makes is to increase understanding of the particular ways in which an alcohol reduction app could be made easy and rewarding to use, findings which may be applicable to other apps aiming to promote self-directed behaviour change.

5.5.1 Make the app easy to use

The finding that participants wanted an alcohol reduction app to be easy to use accords with a considerable literature about the importance to users of simplicity. The Technology Acceptance Model, a theory of the factors that determine use of a technology, posits that people accept or reject a technology based on how easy to use and how useful they perceive that technology to be [448]. Users frequently experience difficulty with new technology [449] and consider ease of use an important and desirable criteria for DBCIs [450]. Ease of use affects users' perceptions of, satisfaction with and intention to use DBCIs [451], moderates continuing engagement with DBCIs [452,453] and may influence the perceived credibility of health information delivered digitally [454].

Ease of use for our participants meant that the app needed to do more than reduce user burden, as important as that is [234,455]. Participants often hesitated before entering information, not because the process itself was difficult but because they wanted to enter the 'right' information and were concerned their entries might not be changeable. They understood that the app's ability to help was at least partly dependent on the accuracy of their input and were keen to ensure they correctly recorded consumption, set realistic goals and created effective action plans. For participants, an easy-to-use alcohol reduction app told them what action was required, gave guidance about how fields should be completed, provided recommendations about, or offered examples of, suitable

entries, and made clear how these entries could be edited. The effectiveness of DBCIs may be enhanced when users are given guidance and direction about how to enact the behaviour [Chapter 3]. Findings from this study suggest that users of DBCIs may also benefit from guidance and direction about how to engage with the technology.

Ease of use was enhanced when the app was aesthetically pleasing. Visually unattractive screens or those heavy with text were described as off-putting, screens with more imagery were praised. Ease of use criteria were also applied to the type of imagery used; some participants found graphs difficult to interpret and preferred data to be displayed in more a simple form by, for example, showing the calories consumed from alcohol in a figure, with a separate figure showing how that differed to the previous week. An aesthetically appealing app can not only increase ease of use but can also enhance the perceived trustworthiness of the information provided. Participants who liked the design of this app said it seemed friendly and safe. A study of how web-based health information was appraised found that a professional design indicated credibility to users [454]. The skills needed to create a visually appealing app fall outside the traditional expertise of behavioural science researchers [187] but the value placed on design by users emphasises the need for expert involvement in the design of DBCIs.

The importance of making the app easy to use was illustrated by participants who seemed resistant to change. These participants were interested in reducing their consumption of alcohol (it was an inclusion criteria for the first study and participants in the second study had searched for and downloaded an alcohol reduction app of their own accord). However, it appeared they could be easily dissuaded from using an app to help by relatively minor ease of use issues. Resistance to change can be overcome in therapeutic settings through the creation of a 'working alliance', formed when the client perceives the therapist as an ally who can help [456]. Findings from this study suggest that ease of use issues may create the impression that the app is not an ally, cannot be

relied upon, and so can be discarded. Resolving ease of use issues may strengthen the relationship between user and app, which could result in more effective interventions [457].

5.5.2 **Make the app beneficial and rewarding**

The Technology Acceptance Model defines the perceived usefulness of a technology as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989, p320 [448]), a definition which reflects the workplace origins of the model. Findings from this study suggest that users of an alcohol reduction app want their technology to be more than just useful. Their needs are for an app that is both beneficial and rewarding.

Health behaviour change can often seem an unrewarding process with immediate costs and remote benefits. Behaviour change is also an often unsuccessful process; most attempts to eat better, exercise more, stop smoking, or drink less alcohol are not maintained long-term [137–140].

Unsuccessful attempts to maintain behaviour can lead to increased negative affect and decreased self-efficacy [378,458] which can result in disengagement from goal pursuit [377,459]. Theories such as Thorndike’s Law of Effect, Operant Learning and Rothman’s Model of Behaviour Maintenance propose that to promote prolonged goal pursuit and encourage maintenance of a new behaviour it may be necessary to positively reinforce change and make salient the beneficial outcomes achieved [141,460,461].

Users want apps that are rewarding to use [462,463] and delete those they find difficult, unhelpful, annoying or burdensome [184,185,234,464]. Smoking cessation, and healthy eating and physical activity apps often seek to provide users with a gratifying experience, either by making use of the app intrinsically rewarding or through positive reinforcement of effort or progress [283,465,466]. Alcohol reduction apps, however, tend not to use reward BCTs [Chapter 2]; findings from this study suggest that may be an omission.

Participants in both studies reported here described a rewarding experience as positive reinforcement in the form of congratulations for achievements (such as recording a no drinking day), recognition for actions (such as setting a goal) and the provision of feedback about progress toward their goals. The app was considered beneficial when it reassured participants about the trustworthiness of the information provided and spoke to them in a friendly, informal and non-judgemental tone. Doubts about the benefits of the app, for example how certain modules might help reduce consumption, were assuaged when participants understood more about why these modules were theorised to work.

5.5.3 Differences between studies

5.5.3.1 Feeling 'lost' and unsure of what to do next

The third theme identified, that of 'feeling lost and unsure what to do next', was identified only among participants in the first study. Participants in the second study reported being able to navigate through the app without great difficulty, perhaps because repeated use resolved their initial confusion. However, users tend not to use new apps repeatedly; more than half the apps downloaded are used less than six times [467]. Therefore, it is not safe to assume that users will resolve issues of initial use without help. The commercial world addresses these problems with a process known as onboarding [468]. Onboarding helps users become familiar with a technology and learn how its use might benefit them. It often takes the form of messages that guide users through the various elements on a screen or a stepped guide that walks users through the process of first using the app. Almost all participants in the first study requested a stepped guide be provided to help them first use the app and many asked that guidance be provided about using elements throughout.

5.5.3.2 'Do not overwhelm me', 'Blame myself, not the app, if it's too hard to use'

Two sub-themes were identified only in the 'think aloud' study: 'Do not overwhelm me' and 'Blame myself, not the app, if it's too hard to use'. Participants in the 'think aloud' study expressed concern that the range of options in the app might present an overwhelming amount of choice, a concern which corresponds with the theory that an excess of choice can inhibit action [469]. Given that this sub-theme was not identified amongst experienced users in the interview study it is possible that people managed issues of overwhelm by using only the modules they found useful, a strategy some participants in the 'think aloud' study had indeed proposed adopting. The presence of the theme of 'Blame myself, not the app, if it's too hard to use' in only the 'think aloud' study may also be explained by the ability of experienced users to solve problems with use. Alternatively, it is possible that the reason that both sub-themes were not found in the interview study is because users who experienced these issues had stopped using the app and so did not respond to invitations to participate.

5.5.3.3 'Update me on how I am doing', 'Be friendly and funny'

The sub-theme 'Update me on how I am doing', could only have been identified in the interview study with experienced users (and not the 'think aloud' study of first time users) because feedback about progress requires repeated use of the app. It is unclear why the sub-theme 'Be friendly and funny', was identified only in the 'think aloud' study. However, one person in the interview study commented that the friendliness of the app increased with use, and evidence suggests that use of a system can increase user satisfaction with that system [470].

5.6 Strengths and limitations

A strength of the current evaluation was the use of two distinct approaches to usability. The first study identified issues with initial use, the second identified issues with repeated use. Identifying and addressing both types of issue are essential if engagement with the DBCI is to be secured. In

addition, the combination of findings from both studies allowed issues common to both first time and repeated use to be identified and given priority. This is important given the likelihood that limited timescales and budget will prevent all possible improvements arising from usability studies from being implemented.

A limitation of the study concerns the representativeness of the sample. A number of participants for the 'think aloud' study were recruited from a convenience sample of members of staff at a London university and their family and friends; the views of whom may not represent those of a typical drinker. Attempts to ensure representativeness were made by ensuring all participants were seeking to reduce their alcohol consumption and had scores on the AUDIT-C questionnaire that represented potentially harmful levels of drinking. Representativeness for the second study was achieved by recruiting participants from users who had downloaded the app unbidden. A second limitation concerned the analysis. Steps to ensure that findings accurately summarised the extracts included multiple readings of interviews and use of a second researcher to verify coding. However, researchers with greater experience in qualitative analyses and/or the evidence on alcohol reduction may have reached additional and/or different conclusions. Care should be taken when generalising these findings: this was a study of a particular alcohol reduction app whose BCTs were implemented in a particular way, findings may not apply to other behaviour change apps. Lastly, some of the participants were known to the first author and were aware of his role in the app's development. It is possible that demand characteristics [471] may have affected these participants' views toward the app.

5.7 Conclusions

First time and experienced users want an alcohol reduction app to be easy, rewarding and beneficial to use. An easy-to-use app would reduce user burden, offer ongoing help and be aesthetically pleasing. A rewarding and beneficial app would demonstrate credibility, provide positive

reinforcement and give feedback about progress. First time users need particular help to become familiar with the app; experienced users need compelling reasons to continue its use.

5.8 Changes made in response to the usability study

5.8.1 Determining which changes to make

Changes arising from the usability study were implemented only if they were in accordance with the aims of the study and also if they either improved, or at the very least did not negatively impact on, the user experience (UX). For example, a change that might make evaluating the effectiveness of one of the modules more difficult was not considered, nor was a change that might result in a poorer UX. Creating a good UX was considered to have comparable importance to answering the research question because it is not possible to reliably evaluate the effectiveness of the modules without participants' repeated use of the app.

Changes meeting both the above criteria were more numerous than could be implemented with the budget and time available. Decisions about which changes to implement were determined in the following order: 1) changes important to participants in both the think aloud study with first-time users and the semi-structured telephone interview study with experienced users were implemented; 2) changes that were requested or suggested by participants in only one study were implemented if they appeared to be commonly held; 3) issues not commonly held were implemented if they appeared highly important to some participants, or if they advanced the aims of the study and/or if they improved the UX. When contradictory requests for change were encountered, the change that most aligned with our research question, or which provided the most positive impact on UX (without detracting from our ability to answer the research question), was implemented.

The changes described below are listed according to module. A table listing changes according to the three themes identified in the usability study ('Feeling lost and unsure of what to do next', 'Make the app easy to use', 'Make the app beneficial to use') can be found in Appendix 8.10.

5.8.2 Self-monitoring and Feedback module

5.8.2.1 Recording drinks

Users valued the ability to record an alcohol free day, so this option was included on the main 'add drinks' screen (Figure 8.25.1) in addition to its previous location in the calendar (Figure 8.25.10). A calendar appears when the date is tapped as this was considered preferable to the back and forward arrows previously used (Figure 8.25.1). An information button was added to the record drinks screen to provide more information about each element on the screen (Figure 8.25.2, 3). The term 'Favourites' was changed to 'Regulars', as some users thought favourites an inappropriate word for an alcohol reduction app (Figure 8.25.1). The alert prompting users to complete their diary was edited to remove any reference to alcohol in order to allay fears of users who were worried about other people knowing they were attempting to reduce their consumption (Figure 8.25.6, 1). The icon for wine was coloured red instead of white as some users had difficulty locating the wine option on the main add drinks panel (Figure 8.25.1).

5.8.2.2 The Mood Diary

Participants commented that the previous approach of comparing no drinking days with drinking days produced inaccurate mood, productivity, clarity and sleep comparisons as they often felt in a positive mood the morning after light drinking (because they had been socialising with friends, for example). Therefore, the Mood Diary was changed to compare no drinking/light drinking days with heavy drinking days (heavy drinking was defined as the consumption of more than six units in a day). The error messages that prompted users to complete required fields was amended to provide information about what questions remained to be answered (e.g. "Please answer if you have any

more drinks to record”) (Figure 8.25.7, 3). An information button was added to provide more information about the purpose of the Mood Diary, how it should be completed and where responses were displayed (Figure 8.25.8, 1).

5.8.2.3 Feedback

Participants in the usability study frequently expressed disappointment that feedback about progress toward their goals was difficult to find. Signposting of feedback was improved by the creation of a new ‘Your achievements’ section, which listed the title for each goal and provided text feedback related to whether the goal was exceeded, hit, nearly hit or missed in the previous week (feedback and icons as described in section 6.3.10.3.2, below). Tapping the title for each goal took users to the Goal Feedback screens described in section 6.3.10.3.2.2, below. The ‘Your achievements’ area also displayed the longest number of continuous days drinking had been recorded (e.g. “Keeping your diary two days in a row”, Figure 8.25.3) in an attempt to encourage regular self-monitoring.

Other changes included making each bar of the Units graph on the dashboard display a summary of drinks for that week when tapped (Figure 8.25.5, 2), and displaying an icon if no units at all were consumed that week (Figure 8.25.3). Lastly, when all tasks within the ‘We suggest’ area had been completed, users were rewarded with a congratulatory message “Good work, you’re all done today” (Figure 8.25.3).

The dashboard previously contained three graphs for each of ‘Units’, ‘Calories’ and ‘Money’. Users noted that the shape of the units, calories and money graph would always be the same, and suggested that alcohol-related calories and money could be better expressed in the form of numbers. Therefore, these graphs were changed to show Calories from (or money spent on) alcohol

this week, the difference between this week and last week and the total calories from (or money spent on) alcohol since the app was downloaded (Figure 8.25.5, 1).

Changes to the calendar consisted of the addition of an orange bar under a date to indicate a light drinking day (previously the calendar showed only red for heavy drinking day, green for a no drinking day and grey for no record). The total number of alcohol free days recorded so far is now shown at the bottom of the calendar (Figure 8.25.10, 1) and each daily record displays the total number of units consumed (Figure 8.25.11, 1).

5.8.3 Action Planning module

Confusion expressed by participants about how to set action plans was addressed in two ways. First, more examples of alcohol-related action plans were provided, adapted from action plans developed by previous users of the app, and made accessible via the information button on the 'Create an action plan' screen (Figure 8.25.13, 2). Secondly, if users tried to save an action plan without both the 'If' and 'Then' fields being complete, a detailed error message directed users to the area that needed completing. For example if the 'Then' area was empty the error message said "Please enter your 'Then' text" (the previous version gave users a generic notification to 'Please complete all fields' Figure 8.25.13, 1). To resolve confusion about when an action plan had been successfully set the app displayed a confirmation message and played a sound after a user had clicked the Save button on the 'Create an action plan' screen (Figure 8.25.13, 3).

5.8.4 Goal setting module

The major change to the goal setting module was to remove the option for monthly goals (which were considered distal goals and therefore less effective) and change the goal period from a rolling week to a fixed Monday to Sunday (which users said they preferred). Otherwise, only minor changes were made to this module. A confirmation message and sound played after a goal had been

successfully set (Figure 8.25.16, 3), small graphical changes were made to improve the legibility of text and some of the sections were renamed in order to clarify the content they contained (e.g. 'Good goal setting' was renamed 'How to set good goals').

5.8.5 Other elements of the app

Eleven of the 12 participants in the first usability study said that the dashboard, the first screen seen after completing registration, was confusing and visually uninspiring and wanted to know what they should be doing when first using the app. To provide this information, the revised version of the app incorporated a guide with three steps: 1) Set a goal; 2) Log some drinks; 3) Explore (Figure 8.29, 2).

These were considered the elements most important to the initial use of the app and were limited to three to prevent overwhelming users with tasks. Once complete, each step was greyed-out and had a green tick added to it in order to provide a sense of accomplishment (Figure 8.29, 2).

An Info button was added to each screen of the app in order to help users understand what the purpose of the screen was, what each element on the screen did and how they should be completed or followed. To help users understand the existence of and purpose of this button, a message appeared on screen alerting users to its presence (Figure 8.29, 3). To avoid over-promoting this feature to the potential annoyance of users, the alert was shown on the 1st, 3rd, 10th and 20th screen visited, after which it was assumed users were aware of the info button's existence and the alert was not shown again.

User burden was reduced by limiting the number of daily tasks that users were asked to complete and renaming the area containing these tasks to a more gentle 'We suggest' from its previous, more directive, title 'Things to do today' (Figure 8.25.3). The only daily task users received was a prompt to record their drinking. Every three days an additional prompt suggested that users visit a different module of the app. Prompts were displayed randomly rather than sequentially in order to ensure

that all modules were promoted equally. Only users in the experimental condition were prompted to use a module; participants in the control condition were not presented with the prompt.

Navigation on the app was improved by ensuring that the tab bar (which sits at the bottom of the screen and provides links to the Dashboard, Progress, Add Drinks, Game and Identity) was retained on all screens; previously it had not been visible on some screens. Bugs where the navigation was broken or did not work as expected were fixed.

The app was improved graphically by adding icons to the dashboard and progress screen (Figure 8.25.17). The tab bar icons were made a little bigger and slightly darker to improve legibility. The text used within the app was made friendlier and more informal. The prompt asking users to rate the app was changed so that it was triggered after the app had been opened seven times rather than three (in order to gain reviews from people who had more experience of using the app).

Any bugs identified by participants in either study or were identified by the research team in their use of the app, which prevented the full functioning of the app, were resolved.

5.8.6 Follow-up

The follow-up procedure was improved in order to reduce the number of users who abandoned the app without completing registration and to increase the number of users who qualified for inclusion in the study.

The original version of the app displayed a welcome screen (required by Apple, containing a logo and the tag line “Get healthy, save money and lose weight, just by drinking a bit less alcohol”), a screen listing key features of the app and the ‘participant information’ screen. To promote the experimental nature of the app from the start, and encourage more participants to complete follow-up measures, the tag line was changed to “Get healthier and help science by using this app”. To make it easier for

users to get to the app's content more quickly, the screen listing key features was removed, leaving just the welcome screen and the 'participant information' screen. The prize draw amount, used as an incentive for users to leave their email address, was increased from £100 to £500. If a user left the email field blank, a prompt reminded them about the scientific nature of the study and the prize draw amount and asked if they wanted to reconsider leaving an email address (Figure 8.28, 3). If they continued to leave the email field blank the prompt was not displayed a second time. In addition to being emailed a link to complete the follow-up questionnaire, the same questionnaire was also presented in the app a month after users had downloaded the app on the 'We suggest' area of the dashboard (Figure 8.25.3).

Registration for the app was simplified in the following ways. A sentence was added to the top of the AUDIT and 'About You' questions to explain why these questions were being asked. The year of birth drop-down field started at 1999 in order to reduce scrolling (users born after that date would be ineligible for the study). A question was added to determine if users were serious about reducing their consumption or just browsing the app (users just browsing were ineligible for the study). The alert asking users to accept notifications from the app was moved to the point where registration was complete, rather than when on first downloading the app as it was thought better to ask permission to notify users after they had gained some benefit from using the app (Figure 8.29, 1).

5.9 Next Steps

The changes made from the usability study as catalogued above were incorporated into the app and this version went through a thorough round of testing by members of the research team before the final version was released. This version was evaluated in a factorial randomised control trial, as described in the following chapter.

6 Evaluating the effectiveness of a smartphone app to reduce excessive alcohol consumption: A factorial randomised control trial

6.1 Abstract

Alcohol consumption is a leading cause of death and morbidity worldwide. Smartphone apps may be able to help people reduce their consumption, however, there is little evidence of their effectiveness. This chapter reports a factorial randomised controlled trial to assess the comparative potential of two sets of techniques, delivered as modules (Self-monitoring and Feedback, and Action Planning) in an alcohol reduction app: *Drink Less*.

6.1.1 Methods

The study design was a between-group factorial randomised controlled trial. Hazardous and harmful drinkers aged 18 or over and willing to make a serious attempt to reduce their drinking were randomised to one of 32 (2^5) experimental conditions after downloading the *Drink Less* app and completing baseline measures. Participants received either an 'enhanced' or a 'minimal' version of each module and were contacted after one month with a follow-up questionnaire. The primary outcome measure was change in past week consumption of alcohol, with analysis based on intent-to-treat, all participants and baseline consumption assumed for missing data. Secondary outcome measures were change in AUDIT score, app usage data and app usability ratings. A factorial between-group ANOVA was conducted to assess main and interactive effects of the modules for the primary and secondary outcome measures.

6.1.2 Results

A total of 672 participants were randomised. At baseline the mean number of units consumed in the past week was 40 and the mean AUDIT score was 19. There was an overall mean reduction in

consumption of alcohol and AUDIT score at follow-up. There were no significant differences in the change in past week consumption or AUDIT score between participants receiving the enhanced and minimal versions of any modules. There was a significant interaction between the Self-Monitoring and Feedback and Action Planning modules, such that a lower AUDIT score resulted when both modules were in their enhanced condition; when either or both modules were in a minimal condition no significant effect on AUDIT score was detected. The app was used for a mean 11.7 sessions per participant and 11.6 screens per session. Sessions lasted a mean of 4 minutes, 23 seconds. Participants given the enhanced version of the Self-monitoring and Feedback module used the app significantly more often, rated it more helpful and more satisfying, and were more likely to recommend the app to a friend, than participants given the minimal version.

6.1.3 Conclusions

Users of the *Drink Less* app reported lower alcohol consumption and a lower AUDIT score at one-month follow-up compared with baseline, but there were no significant differences between those who received enhanced versions of the Self-monitoring and Feedback or Action Planning modules compared with their respective minimal versions. A significant interaction indicated that when enhanced versions of both modules were present, AUDIT scores reduced by more than if only one or neither were present. The enhanced version of the Self-monitoring and Feedback module increased app usability and engagement.

6.2 Background

Excessive alcohol consumption is a major public health issue [1,45]. Alcohol is responsible for approximately 3.3 million deaths worldwide each year and is a causal factor in over 200 diseases and conditions [1,2,19]. In addition to the considerable health costs, alcohol consumption is associated with societal costs such as increased criminal activity and lost productivity [40,42]. Public Health England estimated that alcohol cost UK society £47 billion in 2016 [41].

Face-to-face interventions to reduce alcohol consumption are effective and cost-effective but not widely offered [4,152,472,473]. Digital behaviour change interventions (DBCIs) may be able to overcome some of the barriers associated with the uptake of face-to-face interventions [161,317–319]. A 2016 Cochrane review found that DBCIs reduced alcohol consumption by 23.6 grams of alcohol per week more than controls (equivalent to 2.95 UK units) [7]. Previous reviews and meta-analyses have found similar results [5–7,206–211].

The vast majority of alcohol DBCIs have been offered on web sites. Smartphone apps provide an alternative and promising way of helping people reduce their consumption of alcohol. Tens of thousands of healthcare apps are available [228] and they are downloaded in their billions [229]. However, there has been little evaluation of the effectiveness of healthcare apps in general (e.g. [259–261]) and alcohol reduction apps in particular [274,275]. Three previous trials which experimentally evaluated the effectiveness of apps focussed on people whose alcohol use might affect their treatment for HIV [278] or people with an alcohol-use disorder [276,277]. Determining which behaviour change techniques (BCTs) are most effective for hazardous and harmful drinkers (defined as a score of 8 or more on the Alcohol Use Disorders Identification Test (AUDIT) [31]) is important as this group is responsible for the majority of health, economic and social costs resulting from alcohol consumption [324]. Only one trial of apps aimed at harmful and hazardous drinkers has been published to date to my knowledge [279]. In this trial, participants were given one of two apps:

both provided feedback about current levels of blood alcohol concentration and one also allowed participants to predict their blood alcohol concentration levels at a future event. Neither app significantly reduced alcohol consumption relative to assessment-only controls at seven-week follow-up [279]. This finding suggests that feedback about blood alcohol concentration levels is not, or at least not on its own, an effective BCT in an app. Evidence about the effectiveness of BCTs in web-delivered alcohol interventions is beginning to emerge (Chapter 3, [323]). Apps offer more functionality than websites and smartphones are used in different settings and environments to desktop computers or laptops; different BCTs may therefore be effective. Greater understanding of which BCTs are effective, using what mechanisms of action, is important in the effort of developing more effective interventions [8,320].

Evaluating DBCIs poses several challenges. DBCIs are usually complex and consist of a number of BCTs [9]. An RCT will only be able to determine the effectiveness of the intervention as a whole, not its component parts; nor will it be able to evaluate interactions between active ingredients [474]. Factorial RCTs allow multiple independent variables and interactions between those variables to be evaluated simultaneously, without requiring a large sample size [474]. This makes them highly suited for trials such as this, where the aim is to use the Multiphase Optimisation Strategy [475] to determine which components of an alcohol reduction app should be included in a future trial that compares the app against a minimally active or usual-care control.

In the current investigation of the *Drink Less* app, the component parts contain a number of BCTs. These component parts are referred to as 'modules'; evaluation is conducted at the level of module. Modules are presented to participants in either an 'enhanced' intervention condition; or a 'minimal' control condition. The content of each module is summarised in Appendix 8.11 and detailed in section 6.3.10 of this chapter.

6.2.1 Selecting modules for evaluation

The selection of modules for evaluation was based on four sources of evidence: 1) examination of the BCTs used in alcohol interventions [281]; 2) a formal consensus-building exercise regarding the BCTs that alcohol reduction and behaviour change experts thought most likely to be effective in an alcohol reduction app [16]; 3) a content analysis of the BCTs used within existing popular alcohol reduction apps [Chapter 2]; and 4) a review of published evidence of the effectiveness of alcohol DBCIs [Chapter 3]. On the basis of this systematic development work, five modules were selected as high priority for evaluation in a factorial design: Self-monitoring and Feedback; Action-Planning; Normative Feedback; Cognitive Bias Re-training; and Identity Change. The rationale for selecting the Self-monitoring and Feedback and Action-Planning modules is summarised below (with greater detail in Chapter 4). A separate PhD thesis focuses on the intervention modules of Normative Feedback, Cognitive Bias Re-training and Identity Change, and describes the rationale for their selection [18].

6.2.1.1 Self-monitoring and Feedback

Self-monitoring and Feedback are recommended as effective techniques for alcohol reduction by NICE guidance on behaviour change [15]. Self-monitoring has been found to be an effective BCT in weight management [373,374] and alcohol interventions [281]. Feedback is a key component of face-to-face brief alcohol interventions [389], is commonly included in DBCIs [7] and appears to augment the effect of self-monitoring [382,383]. Self-monitoring and Feedback were both ranked highly by alcohol and behaviour change experts as BCTs likely to be effective in an alcohol reduction app [16].

6.2.1.2 Action Planning

Action planning is recommended as an effective technique by NICE guidance [15]. A form of action plan that enables the setting of if-then conditions for future events [112] (termed 'Implementation

intentions'), has been found to increase goal-attainment rates for health behaviours such as regular breast examinations [476], engaging in exercise [477] and alcohol reduction [114,413,414,478]. Action planning was a BCT ranked highly by alcohol and behaviour change experts as likely to be effective in an alcohol reduction app [16].

Modules were offered in one of two formats. Participants in the intervention received an 'enhanced' version of a module, participants in the control condition received the 'minimal' version of that module. A full description of what is in the enhanced and minimal version of each module is contained below. A table outlining the different conditions participants were assigned to can be found in Appendix 8.13.

6.2.2 Research questions

This study tested the following hypotheses:

1. Participants randomly assigned to the Self-monitoring and Feedback enhanced condition would reduce their consumption of alcohol and/or AUDIT score more than participants assigned to the minimal condition.
2. Participants randomly assigned to the Action Planning enhanced condition would reduce their consumption of alcohol and/or AUDIT score more than participants assigned to the minimal condition.
3. There would be an interaction between the two modules, such that those who receive access to the enhanced version of both modules will reduce their consumption of alcohol and/or AUDIT score more than those receiving access to either one or neither of the modules.

Findings from this study can be taken forward for future research e.g. to determine which, if any, of the modules should be included in a final version of an app that could be evaluated against a minimally active control in a future RCT.

6.3 Methods

6.3.1 Aim

The aim of the study was to evaluate the effectiveness of two intervention modules in reducing excessive alcohol consumption.

6.3.2 Design

The study design was a between-group factorial randomised controlled trial evaluating the effectiveness of two intervention modules 1) Self-monitoring and Feedback and 2) Action Planning. Three other modules are contained within the same app, but evaluated in a separate thesis: 3) Normative Feedback, 4) Cognitive Bias Re-training, and 5) Identity Change [18]. Each module has an 'enhanced' and a 'minimal' version (Appendix 8.11) which yields 32 experimental conditions (Appendix 8.13).

6.3.3 Study sample

Participants were included in the analysis if they were 18 years of age or over at time of download, lived in the United Kingdom, had an AUDIT score of 8 or above (indicative of hazardous and harmful drinking [31]), confirmed they were making a serious attempt to reduce their drinking, and provided an email address.

This study recruited 672 participants to have 80% power (with alpha at 5%, a 1:1 allocation and a two-tailed test) to detect a mean reduction in alcohol consumption of five units between the enhanced and minimal conditions for each intervention module [479]. This assumed a mean of 27 weekly units at follow-up in the control group, a mean of 22 units in the intervention group and a SD of 23 units for both ($d = 0.22$). The sample size was rounded up to the nearest multiple of 32 to ensure all cells were balanced. The estimated effect size is large (comparable with that of a face-to-face brief intervention [4]) and may be considered somewhat unrealistic for a module within a digital

intervention. To address the possibility of non-significant results, Bayes factors were calculated to establish the relative likelihood of the null versus the experimental hypothesis given the data obtained. This permitted a judgment to be made about whether the inclusion of the module in a future version of the app would be more likely than not to have an effect on alcohol consumption.

6.3.3.1 Recruitment

Participants were recruited in a number of ways. The app was listed in the iTunes Store and the listing was optimised according to best practices for achieving a high ranking in app store results (e.g. by the careful selection of keywords) and encouraging people to download the app (e.g. with a well-written description, illustrative screenshots and positive user reviews) [292,480–482]. The app was promoted through organisations such as Public Health England, Cancer Research UK, UK district councils, online communities of people in the UK looking to reduce their consumption of alcohol and a link on a popular smoking cessation app (Smoke Free).

A slow initial pace of recruitment was addressed with the following strategy. The prize offered to users who provided an email address was increased from £100 to £500. Users who left the email field blank were prompted to complete the field before continuing their use of the app (users were only prompted once, if they ignored this prompt they were allowed to continue without leaving an email address but were excluded from the trial). Adverts were placed on Facebook and Google to further encourage downloads. Recruitment continued until 672 eligible users (21 in each condition) were obtained, after duplicate sign-ups were excluded.

6.3.4 Procedure

On first using the app, users were presented with information about the trial and given contact details for the research team. They were asked if they wished to participate in the trial and those who consented were asked to complete baseline measures. Users were then presented with the

AUDIT questionnaire and socio-demographic questions (detailed in Measures, below). On completion of the AUDIT questionnaire users were told their AUDIT score and their AUDIT 'risk zone' (Appendix 8.20). Participants meeting inclusion criteria were randomised to one of 32 (2⁵) experimental conditions after downloading the app. A block randomisation procedure was used to ensure that all groups had an equal number of participants. Randomisation took place by way of an automated algorithm within the app. Participants were blinded to group allocation. The research team were able to see group allocation in order to verify the block randomisation procedure was functioning correctly, but had no contact with participants other than responding to emailed requests for support. Users who did not meet inclusion criteria were allocated to a non-experimental condition that provided access to the enhanced version of all modules. This approach was taken for three reasons: 1) to provide alcohol reduction help to those who were seeking it, 2) to prevent ineligible users from continually re-downloading the app in an attempt to gain full access to modules, and 3) on the basis that positive user reviews are likely to encourage new users to download the app [291,482] - and positive user reviews were considered more likely when users were given the enhanced version of modules.

Follow-up was undertaken by means of a questionnaire emailed to participants one month after download. The follow-up questionnaire consisted of the full AUDIT and questions about app usability (detailed in Measures, below). Non-responding participants were sent a maximum of four emailed reminders. They were also prompted to complete the follow-up questionnaire by means of a note on the app's Dashboard ('We suggest' section, Figure 8.25.3). Duplicate responses were identified and removed before analysis began, with first responses treated as the outcome.

6.3.5 Measures

6.3.5.1 Baseline measures

AUDIT questionnaire, a 10-item questionnaire whose validity as a screening tool for harmful alcohol use has been established [31] and socio-demographic characteristics: age, gender, ethnicity, level of education, country, smoking status, employment status, and interest in reducing alcohol consumption.

6.3.5.2 Outcome measures:

The primary outcome measure was self-reported change in past week consumption of alcohol, which was calculated from the first two questions on the AUDIT using a method reported in a previous study [483]. AUDIT Q1 (How often do you have a drink containing alcohol?) was recoded into number of drinking days per week. AUDIT Q2 (How many drinks do you have on a typical day when you are drinking?) was recoded into the average number of units of alcohol consumed on a typical drinking day. These two variables were multiplied to arrive at a units figure for past week consumption. Change in past week consumption was calculated as the difference between past week consumption at follow-up and baseline. An intent-to-treat analysis was used, such that participants lost to follow-up were retained in the primary analysis and assumed to be drinking at baseline levels.

Secondary outcome measures were: 1) change to the full AUDIT score between baseline and follow-up 2) app usage data, and 3) usability ratings for the app. App usage data was calculated from a log of activities recorded by the app. Usability ratings were: 3.1) How helpful did you find *Drink Less*? 3.2) How easy did you find *Drink Less* to use? 3.3) How satisfied are you with *Drink Less*? 3.4) How likely are you to recommend *Drink Less* to a friend? Usability ratings were scored using a five-point

Likert scale ('not at all', 'slightly', 'somewhat', 'very' and 'extremely'). Analysis of usability ratings was conducted using complete cases only.

6.3.6 Analysis

A factorial between-group ANOVA (Analysis of variance) was conducted to assess main and interactive effects of the five intervention modules on the primary and secondary outcomes. In a sensitivity analysis, ANCOVAs (Analysis of covariance) were conducted to adjust for chance imbalances in socio-demographic and drinking characteristics (gender, age, ethnicity, level of education, employment status, AUDIT score, AUDIT-C score). This examined the robustness of the results in the primary analysis. Socio-demographic and drinking characteristics were reported descriptively. Differences in participant characteristics by module were investigated with one-way ANOVAs for continuous variables and two-sided chi-squared tests for categorical variables.

In the event of a non-significant main effect of an intervention module, Bayes factors were calculated to establish the relative likelihood of the experimental versus the null hypothesis given the data obtained. Bayes factors provide more precise information than is typically obtained using only traditional null hypothesis testing about whether the data support the null hypothesis or are insensitive to detect an effect [484]. Bayes factors were calculated using the online calculator: lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/Bayes.htm with the alternative hypotheses conservatively represented in each case by a half-normal distribution. The expected effect size for the primary calculation of Bayes factors was the same as for the power calculation ($d = 0.22$). In a sensitivity analysis, Bayes factors were also calculated for a smaller effect (reflecting a reduction of three units per week, $d = 0.13$).

6.3.7 Trial registration

The protocol for the trial was registered on BioMed Central. Registered number: ISRCTN40104069

6.3.8 Ethical approval

The trial received ethical approval from the UCL Ethics Committee under the 'optimisation and implementation of interventions to change health-related behaviours' project (CEHP/2013/508).

6.3.9 Availability of data and material

The anonymised dataset is available on the Open Science Framework (<https://osf.io/q8mua/>). All code and content for the app has been made available under an open source license (Appendix 8.31).

6.3.10 Intervention

Drink Less is an app available for iOS (Apple's operating system for smartphones) devices that is designed to support a user³ making a serious attempt to reduce their consumption of alcohol. There was a pragmatic, methodological need to structure the app around an activity that would engage all participants and allow experimental manipulation of other supporting modules (section 4.4.5 elaborates on the rationale for this decision); therefore, the app asks all participants to set a goal to reduce their alcohol consumption. Participants are given access to other modules in either an enhanced or minimal condition. The content of the five intervention modules is summarised in Appendix 8.11 and 8.12. A full description of how the two modules evaluated in this thesis were implemented in the app, as well as how the goal setting module was implemented, is described below.

³ 'Users' refers to all users of the app. 'Participants' refers to users who have been screened into the study

Drink Less was made freely available to download from the UK version of the Apple App Store for people who were using iOS8 or above. No changes were made to the app during the course of the trial. The latest version of the app can be downloaded from the web site created for this study: drinklessalcohol.org. The app is not, as of April 2017, available outside the UK.

6.3.10.1 How decisions about what to include were made

The app building process requires numerous decisions to be made about the form and function of every element on every screen. These decisions can increase engagement, encourage data entry, create a positive user experience and promote behaviour change. Apps that are easy and rewarding to use are likely to be used more often [Chapter 5] and are more likely to receive positive reviews and word-of-mouth recommendations, which may lead them to be chosen in preference to the similar apps that exist [291,482].

Decisions regarding implementation of the modules were informed by the published research literature for usability and user experience (e.g. [189,366,485,486]), Apple's iOS Human Interface Guidelines [487], regular consultations with the research team, and recommendations from the software developers. Module implementation was later refined in response to feedback from the usability study [Chapter 5].

In addition, alcohol reduction apps downloaded for the content analysis study [Chapter 2] were used and informally reviewed for the approach they had taken to implementing self-monitoring, feedback, action planning and goal setting. The aim was to gather understanding of what the experience was like of using these particular BCTs and the app as a whole. Goals and action plans were set, drinks were recorded and feedback was noted. The questions asked included: was the process of entering data straightforward and intuitive; did it result in a positive or negative change in affect; was entering data something that seemed beneficial to repeat; was the process as a whole

something that should be learnt from or avoided? For example, when recording consumption, some apps allowed users to choose their drink from a list. However, there are over 1,500 different bottled ales in the UK [488], with more added on a regular basis and hundreds of other types of beer, wine or spirits available; any list of alcoholic drinks was unwieldy to use, is bound to be quickly out-of-date, and was, as such, impractical. In addition to using the apps, user views toward the implementation of BCTs were informally studied by examining reviews left on the app stores. For example, users expressed frustration with an inability to set exact levels of ABV (alcohol by volume) in the NHS DrinkTracker app; a drink could be 4%, 4.5% or 5%, but not 4.6%, 4.7% or 4.8%. A need for this level of precision was a determining factor for some users, who commented that they would choose an app on that basis alone. This work informed the brief given to the app developers which outlined how we wanted each of the modules to be implemented. Implementation was later refined by internal testing (section 6.3.10.6.2) and the usability study [Chapter 5].

6.3.10.2 Screening and baseline questionnaire

On opening the app for the first time users were presented with a welcome screen with text reminding them of its experimental nature (the description on the Apple App Store also contained information that the app was a scientific experiment, Figure 8.30). Users were then shown the ‘participant information’ screen that provided details about the study and gave contact information for the research team (Figure 8.28, 1). At this point, users could either stop using the app or press the ‘I consent to participate in the study’ checkbox, which subsequently made the ‘Continue’ button ‘tappable’ (Figure 8.28, 1).

On tapping ‘Continue’ the Alcohol Use Disorders Identification Test (AUDIT) was presented to all users. The display of questions on the AUDIT was designed to reduce the high rates of attrition associated with asking an excess of questions at an app’s registration point [489]. If an answer indicated subsequent questions were unnecessary those questions were hidden, allowing users to

skip straight to the next relevant question. The questions themselves were displayed in a way that meant they could be answered with a single tap, many app forms require two taps for an answer (one to open a list of possible responses, the second to select a response). Text at the top of the screen explained why the questions were being asked and a progress bar at the bottom showed users their position in the registration process (Figure 8.28, 2). Brief feedback about AUDIT scores followed WHO guidance [31], full details of which can be found in Appendix 8.20.

Baseline demographic questions (age, ethnicity, educational status, country, smoking status, employment status, email address and reason for using the app) were the third and final stage of registration (gender was asked on the AUDIT questionnaire).

6.3.10.3 How Self-monitoring and Feedback were implemented

6.3.10.3.1 Self-monitoring

6.3.10.3.1.1 Recording drinks

Self-monitoring is the most commonly included BCT in alcohol reduction apps available in the UK [Chapter 2], and is a feature considered highly important to users of a web-based alcohol intervention [312], users of an alcohol use disorder app [490], users of alcohol reduction apps [491] and users of the app developed for this thesis [Chapter 5]. A well-implemented self-monitoring module is, therefore, important for meeting user needs and may help the app be chosen in preference to others available.

The main aim when building the self-monitoring module was to make the process of recording drinks as easy as possible. Large numbers of users stop using health apps if they find data entry too burdensome [234], users of alcohol reduction apps often criticise the process of recording drinks [491] and interventions which greatly increased the frequency of self-monitoring have been found to

produce small-to-medium-sized improvements in goal attainment [325]. Simplifying the process of entering drinks may lead to greater use of this module and a corresponding increase in intervention effectiveness.

The self-monitoring module was made easy to use in the following ways. The link for adding drinks was made larger than other links and placed in the centre of the navigation tab bar, indicating its importance to participants and making it easy to find (Figure 8.25.1). Tapping this link allowed participants to choose from six categories of drinks (beer, cider, wine, fortified wine, spirits, or alcopops, Figure 8.25.1). Once a drink category had been selected, participants were presented with a screen allowing them to enter more details about the drink, such as its ABV (alcohol by volume), size, quantity and price (Figure 8.25.2, 2. A full list of the type of drinks and options available for each can be found in Appendix 8.21).

A participant could accept the default entries and click the Save button without entering other information. This reduced the process of adding drinks to the minimum number of steps, whilst allowing participants to add more detail should they wish. Reducing steps required default options to be carefully selected in order to minimise the likelihood of inaccurate recording. The default type of drink (e.g. for beer: lager, for wine: red) reflected the most popular type of that drink in the UK [492]. There does not appear to be data about the most common volume of an alcoholic drink, defaults were therefore chosen on the volume users may be most familiar with (e.g. for beer: pint) or that reflect the median volume available in pubs or restaurants (e.g. for wine: a 175ml glass). The default ABV was calculated from a mean of the ABV from popular drinks of that type, rounded up to the nearest integer (the decision to round up rather than down was made in order to overestimate rather than underestimate the number of units an individual had consumed). No default price was set, as prices for alcoholic drinks vary widely throughout the UK.

Use of the self-monitoring module was made easier with the addition of links for 'Regulars' and 'Recent' (Figure 8.25.1). Regulars contains a list of saved configurations of type, ABV, size and price of a drink. Recent contains all the drinks the participant has previously entered, sorted by date, most recent first. Tapping any of the drinks on either of these screens restores the previous configuration of type, ABV, size and price. These configurations can either be edited or saved.

Participants were reminded to complete a log of their drinking at 11:05am each morning, though the reminder time could be changed. The default was set for about eleven o'clock in order not to disturb late risers and to allow participants time to complete their morning routine. It was set for just past the hour in order not to conflict with other reminders set for that time. Setting reminders to just past the hour is an approach taken by the popular diet and fitness logging app, MyFitnessPal. Reminders took the form of an on-screen alert (Figure 8.25.6, 1), a 'Badge App icon' (Apple's name for the red dot which appears on an app's icon on a participant's home screen, Figure 8.25.6, 2) and a prompt on the participant's dashboard of the app (Figure 8.25.6, 3).

6.3.10.3.1.2 The Mood Diary

In addition to self-monitoring consumption, participants were also encouraged to monitor the consequences of consumption by way of a Mood Diary that asked them to rate their mood, productivity, clarity and sleep quality on a scale of 0-10 on a daily basis (Figure 8.25.7). Scores on mornings after nights of heavy drinking were compared with scores on mornings after nights of light or no drinking, and displayed in graphs (section 6.3.10.3.2.4, below).

The potential effectiveness of increasing understanding about the consequences of alcohol consumption is supported by the PRIME Theory of motivation. PRIME Theory posits that behaviour is determined on a moment-to-moment basis by whichever competing impulse or inhibition is strongest at the time, and that enacting a new behaviour requires activating wants and needs strong

enough to overcome competing impulses or inhibitions [93,94]. Enacting a new alcohol behaviour in the moment can be challenging because alcohol increases impulsivity, impairs inhibitory control and increases attentional bias for alcohol-related cues [48,60,68,362]. It was reasoned that increasing salience about the consequences of consumption on next-day mood, productivity, clarity and sleep quality, may reduce impulsive attitudes towards alcohol consumption and increase the motivation not to drink.

The four consequences of consumption were chosen on the basis of evidence. The residual effects of alcohol can impair productivity, increase absenteeism and affect self-reported feelings of ability to perform [493–496]. Alcohol can impair next-day academic performance [497], pilot performance [498] and concentration [499]. It can affect next-day mood states [500], increase self-reported anxiety, irritability and depression [501,502] and results in a poorer sense of overall well-being [503]. The effects of alcohol on sleep are well-documented. Whilst alcohol is a sedative and can induce the rapid onset of sleep [504], the sleep that ensues is negatively affected. Alcohol can disturb the second half of the night sleep [505], resulting in reduced sleep, increased light sleep and frequent awakenings [497,501,506]. Alcohol can have extensive effects on daytime sleepiness [506] and may result in post-consumptive daytime impairment [504].

At the end of the Mood Diary questions were two additional questions. The first asked participants if they had any other drinks to record and displayed the date of their last recorded entry to prompt recollection of drinking behaviour since that point (Figure 8.25.7, 2). The second asked participants if they drank more than they wanted to yesterday. If participants answered ‘No’ they were subsequently asked “What helped you achieve your goal?” If they answered ‘Yes’ they were asked “What got in the way?” (Figure 8.25.7, 2). Responses to these questions were displayed in the ‘What worked and didn’t work’ screen of the app (described in section 6.3.10.3.2.7 below).

6.3.10.3.2 Feedback

There were two main aims for the feedback element of this module: 1) provide feedback about consumption and the consequences of consumption (calorie intake, spend on alcohol, and how mood, productivity, clarity and sleep quality are affected by heavy drinking); and 2) provide feedback about progress toward goal(s), celebrate successes, and avoid using language that might be interpreted as judgemental or discouraging. In addition, audible or visual feedback given after participant actions (for example after recording a drink or setting a goal), was intended to provide a sense of accomplishment and positive reinforcement that may encourage repeated use of the app.

The second aim for the feedback module was intended to prevent goal disengagement. The challenge with interventions that facilitate goal setting is to encourage participants to set goals that are difficult but attainable. Difficult but attainable goals result in high levels of performance [128], goals that appear to be unattainable can result in goal abandonment [133–136]. In order to help users set appropriate goals, the app provided positive reinforcement when goals were met and motivational feedback when goals were missed. If goals were missed by a substantial amount twice in a row, feedback suggested that the goal may presently be too difficult as to be attainable and that the participant might want to change their goal to one that is slightly easier. If goals were exceeded by a substantial amount twice in a row, feedback suggested that the goal may be too easy as to be rewarding and that the participant might want to make their goal more difficult. Feedback in both cases was presented as advisory rather than directional and was only delivered after goals were missed twice in a row in order to account for periods of unusual drinking activity such as celebrations or fasts, and the text shown to participants asked them to consider whether this was an unusual period before changing their goal (Figure 8.25.9, 1). When tapped, this text took participants to the goal setting screen, where information on good goal setting was again presented. Full details of the goal feedback provided can be found in Appendix 8.22.

A 'substantial amount' was selected as $\geq 20\%$ above or below the target goal. I.e. if a participant set a goal of 20 units a week and drank 24 units or above for two weeks in a row they would receive feedback suggesting the goal may be too difficult. If they set the same goal and drank 16 units or less for two weeks in a row they would receive feedback suggesting the goal may be too easy. The 20% figure was chosen as it allows for mildly discrepant goal performances and so may promote continued goal striving, whilst encouraging participants to address the more substantial discrepancies that may result in goal abandonment.

6.3.10.3.2.1 Dashboard

The dashboard contained a number of feedback elements. The units graph displayed the amount of alcohol consumed per week since the app was downloaded (Figure 8.25.3), with a horizontal line to indicate the position on the y-axis of a participant-set unit goal (if a participant had not set a unit goal the line was placed at 14 units to reflect UK government guidelines [32]). Each bar on the graph could be tapped to display a summary of the drinks consumed that week (e.g. 3 x glasses of red wine, 2 x pints of beer, 2 x whiskeys), accompanied by totals of the number of alcohol free days, units consumed, amount spent on and calories consumed from alcohol; and how those figures compared with the previous week (Figure 8.25.5, 2). The calorie tab displayed the total number of calories consumed from alcohol during the current week, how that figure compared to the previous week and the total number of calories consumed since the app was downloaded (Figure 8.25.5, 1). The money tab showed the same information as the calorie screen but in terms of spend on alcohol.

6.3.10.3.2.2 Goal feedback

The dashboard provided a link to feedback that demonstrated how the participant had performed against their goal(s) to date; and brief summary feedback about how they were performing against their goal(s) in the current week (Figure 8.25.4, all goals ran from Monday to Sunday). Feedback

about how the participant had performed against the goal to date consisted of three screens: Last week, Hit Rate and Success Rate.

6.3.10.3.2.2.1 Last week

The 'Last week' screen provided feedback about goal progress for the last complete week. Information displayed was: the goal title (e.g. "Goal: Have at least 3 alcohol free days a week"), the period covered (e.g. "Last ended: 28 November 2016"), the number of units consumed, calories consumed, alcohol free days or spend on alcohol (e.g. "Alcohol free days; 5") an icon to reflect whether a participant had exceeded (green circle), hit (green tick), nearly hit (orange circle) or missed (red cross) the goal. Below the icon, text feedback that tallied with the participant's success or otherwise was given (e.g. "Congratulations on a great week of achievement. Feel proud? You should." Figure 8.25.9, 1). Appendix 8.22 contains full details of all goal feedback provided.

6.3.10.3.2.2.2 Hit rate

The 'Hit Rate' screen displayed feedback in a bar chart that detailed success against the goal to date, one bar for each week. A horizontal line indicated the participant's target and text below the chart summarised their success so far (e.g. "You've hit 50% of your goal to drink less than 19 units a week", Figure 8.25.9, 2).

6.3.10.3.2.2.3 Success rate

The 'Success Rate' screen provided feedback about how frequently a goal had been exceeded, hit, nearly hit or missed and displayed the information in pie chart form. Text below the chart informed participants how many times in a row they had hit their goal (Figure 8.25.9, 3).

6.3.10.3.2.3 Feedback about current week's goal(s)

Feedback about performance against the goal in the week to date was displayed on the dashboard in the 'Your active goals' area and consisted of the goal title, information about current level of

progress against goal(s) and length of time before the goal ends (e.g. “Drink less than 19 units a week; So far 8 units, ends in 3 days”, Figure 8.25.4). For participants who had recently downloaded the app and not completed a whole week, the dashboard showed how long before goal feedback would be given (i.e. how long until the next Monday).

6.3.10.3.2.4 Your hangover and you (feedback from the Mood Diary)

‘Your hangover and you’ contained four graphs which compared a participant’s mood, productivity, clarity and sleep quality on days after heavy drinking with days after light or no drinking (Figure 8.25.8, 2). Heavy drinking days were defined as more than six units per day for men or women, which reflects UK government guidelines [32]. Scores for this graph were taken from entries a participant had made to the Mood Diary questions (described in section 6.3.10.3.1.2, above).

6.3.10.3.2.5 Calendar

The calendar displayed dates in month form, beneath which were bars coloured green to provide feedback about a no drinking day, orange for a light drinking day (greater than zero units but less than six units), red for heavy drinking day (more than six units), grey for no record entered. The calendar also showed the total number of alcohol free days since the app had been downloaded (Figure 8.25.10, 1).

Each day of the calendar could be tapped to see a list of drinks recorded for that day. The daily record showed details for each drink (its name, size, number of units and calories) as well as the total number of units consumed from all drinks (Figure 8.25.11, 1).

Days where a drinking record had not been entered were marked in grey on the calendar. Tapping these days displayed text that adhered to the Timeline Follow-back procedure and prompted participants to look at their diary, text messages or emails to jog their memory of their drinking for that day [507] (Figure 8.25.11, 1). If participants tapped the Alcohol Free Day button a pleasing

sound and animation played, with a large green tick and “Keep up the good work!” displayed (Figure 8.25.10, 3).

6.3.10.3.2.6 Add drinks panel

An alcohol free day could also be recorded on the main Add Drinks screen. When tapped, a pleasing sound and animation played and a tick and “Keep up the good work!” was displayed, similar to the positive feedback given when an alcohol free day was recorded on the calendar (Figure 8.25.1).

6.3.10.3.2.7 What has and hasn’t worked

The ‘What has and hasn’t worked’ screen displayed entries to the question in the Mood Diary that asked “Did you drink more than you wanted to yesterday?” (described in section 6.3.10.3.1.2, above). Responses were listed in the respective part of the ‘What has and hasn’t worked’ screen (Figure 8.25.8). This screen was intended to help participants remind themselves of the behaviour that had promoted or prevented goal attainment.

6.3.10.3.3 Behaviour change techniques

BCT	App Location	Thesis section
1.5 Review behaviour goals	Dashboard/ Goal feedback	6.3.10.3.2.1/ 6.3.10.3.2.2
1.6 Discrepancy between current behaviour and goal	Dashboard/ Goal feedback/ Calendar	6.3.10.3.2.1/ 6.3.10.3.2.2/ 6.3.10.3.2.5
2.2 Feedback on behaviour	Dashboard/ Goal feedback	6.3.10.3.2.1/ 6.3.10.3.2.2
2.3 Self-monitoring of behaviour	Add drinks	6.3.10.3.1.1
2.4 Self-monitoring of outcomes of behaviour	Mood Diary	6.3.10.3.1.2
2.7 Feedback on outcomes of behaviour	Your hangover and you	6.3.10.3.2.4
5.2 Salience of consequences	Dashboard	6.3.10.3.2.1
5.6 Information about emotional consequences	Mood Diary	6.3.10.3.1.2

10.3 Non-specific reward	Add drinks confirmation	6.3.10.3.1.1
10.4 Social reward	Dashboard/ Calendar	6.3.10.3.2.1/ 6.3.10.3.2.5
10.9 Self-reward	Goal feedback	6.3.10.3.2.2

6.3.10.3.4 Experimental vs control group features

Participants assigned to the experimental group and given the enhanced version of the module were prompted to complete a log of their alcohol consumption and answer the Mood Diary questions on a daily basis. They were also given all the feedback above.

Participants assigned to the control group and given the minimal version of the module were only asked to complete a log of their alcohol consumption, they were not presented with the Mood Diary questions (Figure 8.26, 3). Participants assigned to the control group were not given any feedback: their dashboard did not display any graphs, there was only very brief information about goal progress and they were given no feedback about goal performance (Figure 8.26, 1). The information button on the Dashboard that displayed more information about the dashboard and Mood Diary contained different text for participants in each group (Figure 8.26, 2).

6.3.10.4 How Action Planning was implemented

The two aims when building the Action Planning module were: 1) make setting action plans as easy as possible, and 2) help participants understand why they should set an action plan in the first place. ‘Action plan’ was the term used within the app, in place of the more accurate, but potentially less well-understood, ‘implementation intentions’.

On launching the Action Planning module (accessed via ‘Create and View action plans’ on the ‘Progress’ screen of the app, Figure 8.25.12, 1), participants were presented with information that briefly explained the benefits of setting an action plan and provided an example of one. The If/Then elements of an action plan were distinguished graphically to help establish that an action plan

needed to include both a cue and a response (Figure 8.25.12, 2). Also on this screen were three links to different action plan-related content: ‘Create an action plan’; ‘Your action plans’; and ‘Why set an action plan?’ (Figure 8.25.12, 2). An information button provided help on using the screen.

6.3.10.4.1 Create an action plan

‘Create an action plan’ contained a field for each of the ‘If’ and ‘Then’ components of an action plan, text within each field reminded participants what content should go in each (Figure 8.25.13, 1). If a participant attempted to save an action plan with one or other of the fields empty, an error message directed them to the part that needed completing (Figure 8.25.13, 1). An information button provided numerous examples of action plans (Figure 8.25.13, 2).

6.3.10.4.2 Your action plans

‘Your action plans’ provided a list of all the action plans a participant had set (Figure 8.25.14, 1). The ‘If’ of each action plan was displayed in list form and could be tapped to display its associated ‘Then’. The display of the ‘Then’ was subtly animated in order to provide a more enjoyable user experience.

6.3.10.4.3 Why set an action plan

‘Why set an action plan’ contained more details about the benefits of setting action plans, examples of action plans and evidence to support their effectiveness (Figure 8.25.12, 3).

6.3.10.4.4 Behaviour change techniques

BCT		App Location	Thesis section
1.4	Action planning	Create an action plan/ Your action plans	6.3.10.4.1/ 6.3.10.4.2
9.1	Credible source	Why set an action plan	6.3.10.4.3

6.3.10.4.5 Experimental vs control group features

Participants assigned to the experimental group and given the enhanced version of the module were given access to all three action plan screens, detailed above. Participants assigned to the control group and given the minimal version of the module were only given access to a single screen with basic text information about action plans (accessed via 'Create and View action plans' on the 'Progress' screen of the app, Figure 8.25.17).

6.3.10.5 How goal setting was implemented

The aims when building the goal setting module were to offer participants a selection of goals, help them determine what a suitable difficult, specific and proximal goal might be and make the process of setting goals as easy as possible.

On launching the goal setting module (accessed via 'Create and view goals' on the 'Progress' screen of the app, Figure 8.25.17), participants were presented with two links to other screens ('Set and view goals'; and 'How to set good goals') and the question "I want to drink less because..." (Figure 8.25.15, 1). This question was intended to help participants establish an overarching reason for reducing their alcohol consumption; responses were prominently displayed on the Dashboard, at the top of the 'Your active goals' area (Figure 8.25.4).

6.3.10.5.1 Set and view goals

'Set and view goals' contained a list of all active goals and any previously set goals (goals that had either been deleted or whose end date had passed). Text briefly explained some of the principles of good goal setting and a prominent button at the bottom of the screen allowed participants to set a new goal (Figure 8.25.15, 2). An information button provided more help on using this screen (Figure 8.25.15, 3).

6.3.10.5.2 Set a new goal

Participants could choose between four types of goal: units, spending, calories and alcohol free days (Figure 8.25.16, 1). Whilst a participant could set a goal to any level they wanted, default options provided guidance about potentially suitable goals. The default unit goal was 14 (which reflects UK government guidelines for weekly alcohol consumption for both men and women [32]), the default calorie goal was 1,100 (which equates to the approximate calorie equivalent of 14 units of average strength beer or wine) and the default number of alcohol free days was 3 (following recommendations by the Royal College of Physicians [508] and UK Government guidelines [32]). No default was set for spending because the price of alcoholic drinks varies considerably throughout the UK. Goals were automatically set to recur every Monday but participants could deselect this option if they wished. If a unit goal was chosen participants could click a link to see the number of units in typical drinks (Figure 8.25.16, 2). On tapping the 'Save' button a pleasing sound was played and confirmation message appeared to let participants know they had successfully set a goal (Figure 8.25.16, 3). An information button provided more help on using this screen.

6.3.10.5.3 How to set good goals

'How to set good goals' contained brief information about good goal setting, a list of the types of goal that could be set and a suggestion of the next steps participants should take.

6.3.10.5.4 Behaviour change techniques

BCT		App Location	Thesis section
1.1	Goal setting (behaviour)	Set and view goals	6.3.10.5.1

6.3.10.6 The build process

6.3.10.6.1 Choosing a developer and platform

The desired implementation of modules was described in 'wireframes', a visual guide that detailed in rough form the content for each screen. Four app development companies were sent these wireframes and a briefing document which summarised the app's objectives, its key elements, the requirements of a developer, the technical and intellectual property requirements and timescales for completion (Appendix 8.24). Two companies declined to quote, two others returned a proposal and quote. Portable Pixels quoted £22k for two 'native' apps, Pocket Apps quoted £28k for an app built in HTML5.

A 'native' app runs on a specific computer operating system (i.e. one app would be built for Apple smartphones and a separate app for Android), an HTML5 app runs on different operating systems (i.e. the same app would work on both iOS and Android). HTML5 apps run more slowly than native apps [509], and use more device memory [510]; issues which may have an impact on participant engagement [511]. Native apps provide a better user experience [512] and can access the core features of the app more easily [513]. Some features, such as the push notifications required to prompt users to perform certain actions, may not be accessible on HTML5 apps [514].

The advantages of native apps and the preferential quote from Portable Pixels led to their selection for this project. However, given a limited budget and the desire to create iterative versions of the app it was decided to develop on a single platform only, rather than both platforms as had originally been planned. The two main platforms for apps are iOS (iPhone, iPad) and Android. Whilst iOS has fewer users than Android [515] it is considered an easier platform to develop and test on due to the number of different Android devices, browsers and implementations of their operating system [516]. Therefore, iOS was chosen as the development platform.

6.3.10.6.2 Testing and iterating

An 'agile' development methodology was adopted [517], this delivered working software at regular intervals and allowed modules of the app to be tested before the app had been built in its entirety. Testing was an extensive and repeated process that involved ensuring not just that all elements worked but that they worked optimally. Paper layouts such as wireframes are a useful guide to development; however, functionality, layout, design and text can only be judged suitable when viewed in the context of the app environment. Consequently, modules went through numerous iterations between their design in the wireframes and the version released to the public.

As mentioned in section 6.3.10.2 (above) attention was focussed on testing the first few screens of the app as these usually result in the greatest amount of attrition [467]. All registration screens went through numerous iterations in order to ensure they were both easy and rewarding to use. The other area most iterated was the self-monitoring module, as this is critical to the feedback module, is a feature users specifically seek out in an alcohol reduction app [312,491] and its data entry elements impose most burden on a user. Therefore, the considerable time and money spent iterating this module toward its most usable form was considered appropriate for experimental and user experience purposes.

Informal testing was undertaken by all members of the research team, their friends and family, and other staff and students at UCL. Testing included the app's text, design and functionality, the registration and randomisation process, the content different groups were exposed to and the fidelity of data storage. The app build started in September 2014 and a first version was released for testing in May 2015. Formal testing took the form of a usability study of user views toward the app [Chapter 5].

6.4 Results

The first 672 users who met inclusion criteria after the trial was launched on May 18th 2016 were randomised equally to the 32 intervention groups (Appendix 8.13), 21 participants in each group. Trial recruitment was completed on the 10th July 2016. One hundred and seventy-nine participants (27%) responded to follow-up, but all participants were included in the primary analysis (Figure 6.1). No significant between-group differences on rates of attrition were found. An intent-to-treat analysis was used and participants not responding to follow-up were assumed to be drinking at baseline levels.

6.4.1 Participant characteristics

The majority of participants were female (56%), white (95%), employed (87%), non-smokers (75%) and had post-16 educational qualifications (72%); details of all participant characteristics can be found in Table 6.1. Participants had a mean age of 39. The mean number of units consumed in the past week was 40, the mean AUDIT score was 19 and two-thirds of participants had an AUDIT score equal to or greater than 16, which indicates harmful levels of alcohol use. There were two differences in characteristics between participants assigned to the two modules: participants who received the minimal versions of the Self-monitoring and Feedback module and the minimal version of the Action Planning module were significantly more likely to be employed than participants receiving the enhanced version of those modules.

Table 6.1: Participant characteristics at baseline: Mean (n), unless stated.

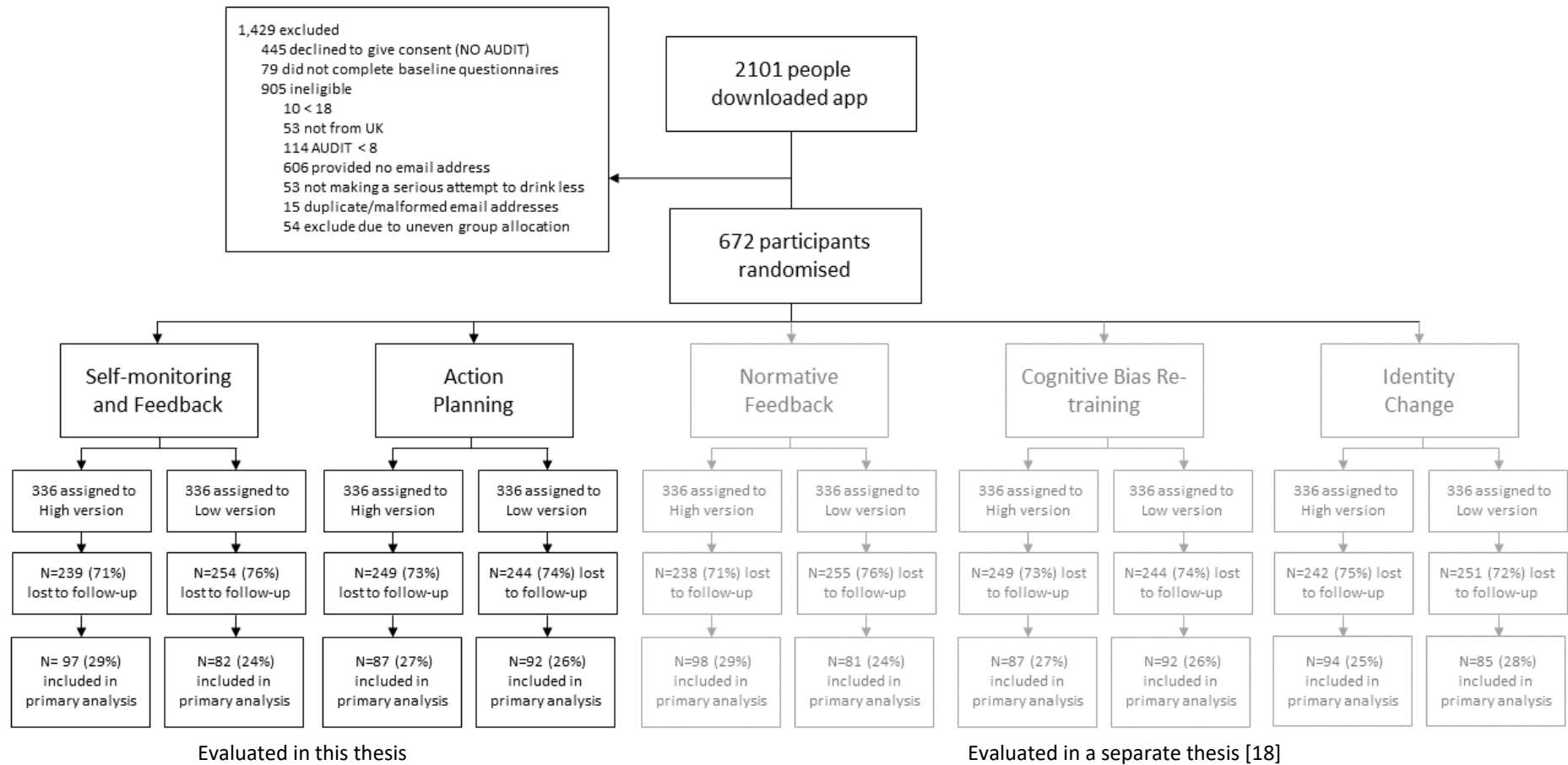
	Self-monitoring and Feedback			Action Planning		Normative Feedback		Cognitive Bias Re-training		Identity Change	
	All	Enh.	Min	Enh	Min	Enh	Min	Enh	Min	Enh	Min
% Employed	86.5 (581)	83.6* (281)	89.3* (300)	83.0* (279)	89.9* (302)	86.9 (292)	86.0 (289)	87.5 (294)	85.4 (287)	86.9 (292)	86.0 (289)
% Post-16 qualifications	72.0 (484)	72.6 (244)	71.4 (240)	72.0 (242)	72.0 (242)	72.0 (242)	72.0 (242)	72.6 (244)	71.4 (240)	72.0 (242)	72.0 (242)
% White	95.2 (640)	94.6 (318)	95.8 (322)	95.2 (320)	95.2 (320)	95.5 (321)	94.9 (319)	95.2 (320)	95.2 (320)	95.2 (320)	95.2 (320)
Age (SD)	39.18 (10.92)	39.4 (11.46)	38.9 (10.36)	39.4 (11.44)	39.0 (10.39)	38.3* (10.14)	40.0* (11.60)	39.4 (10.92)	39.0 (10.93)	39.9 (11.02)	38.5 (10.78)
% Women	56.1 (377)	59.2 (199)	53.0 (178)	57.1 (192)	55.1 (185)	55.1 (185)	57.1 (192)	56.3 (189)	56.0 (188)	53.3 (179)	58.9 (198)
% Current smokers	24.6 (165)	24.4 (82)	24.7 (83)	22.6 (76)	26.5 (89)	25.0 (84)	24.1 (81)	24.4 (82)	24.7 (83)	23.2 (78)	25.9 (87)
PWC Units (SD)	39.9 (27.34)	39.9 (27.09)	39.9 (27.63)	39.0 (26.46)	40.9 (28.20)	39.1 (25.97)	40.7 (28.66)	40.3 (28.23)	39.6 (26.45)	39.0 (26.62)	40.8 (28.05)
AUDIT-C score (SD)	9.4 (1.85)	9.4 (1.86)	9.4 (1.84)	9.4 (1.78)	9.4 (1.92)	9.4 (1.77)	9.4 (1.92)	9.4 (1.95)	9.4 (1.74)	9.4 (1.76)	9.4 (1.93)
AUDIT score (SD)	19.1 (6.56)	18.9 (6.44)	19.2 (6.69)	19.0 (6.68)	19.1 (6.45)	19.2 (6.49)	18.9 (6.63)	19.2 (6.75)	18.9 (6.37)	19.0 (6.35)	19.2 (6.77)
% AUDIT ≥16 ^a	66.7 (448)	67.3 (226)	66.1 (222)	66.1 (222)	67.3 (226)	67.6 (227)	65.8 (221)	68.2 (229)	65.2 (219)	66.7 (224)	66.7 (224)

SD = Standard deviation. PWC = Past week consumption. Enh. = Enhanced version of module. Min = Minimal version of module

^a indicates harmful drinkers and drinkers at-risk of alcohol dependence as defined by the AUDIT

* indicates cases where there was a significant difference in a participant characteristic between versions of an intervention module

Figure 6.1 Trial profile



6.4.2 Effects of the intervention modules on change in alcohol consumption and change in AUDIT score

Using an intent-to-treat analysis, where non-respondents were assumed to be drinking at baseline levels, a factorial between-group ANOVA found numerically larger reductions in consumption for the enhanced version of the Self-monitoring and Feedback module compared to the minimal version of the module. However, there was no significant difference between the enhanced and minimal Self-monitoring and Feedback module ($f = 0.78$; $p = 0.38$) or the enhanced and minimal Action Planning module ($f = 0.13$; $p = 0.71$) on the primary outcome measure of change in alcohol consumption (Table 6.2), indicating that neither experimental group significantly reduced their consumption relative to controls. Similarly, there were numerically larger reductions in AUDIT score for the enhanced versions of both the Self-monitoring and Feedback and Action Planning modules compared to the minimal versions. However, no significant differences were found between the enhanced and minimal Self-monitoring and Feedback module ($f = 0.35$; $p = 0.56$) or the enhanced and minimal Action Planning module ($f = 1.75$; $p = 0.19$) on the secondary outcome measure of change in AUDIT score (Table 6.3), indicating that neither experimental group significantly reduced the AUDIT score relative to controls.

There was a significant interaction between Self-monitoring and Feedback and Action Planning ($F(1,656) = 5.90$; $p = 0.02$), such that there was a greater reduction in AUDIT scores when both modules were in their enhanced versions than when either or neither were (Table 6.4). An independent samples t-test found a significant difference in AUDIT score for participants receiving Self-Monitoring and Feedback enhanced and Action Planning enhanced (mean: -1.18 ; SD: 3.15 ; $n = 168$) compared with participants who received either or both modules in their minimal condition (mean: -0.60 ; SD: 2.39 ; $n = 504$); $t(670) = -2.52$; $p = 0.01$).

A table of interactions for change in past week consumption can be found in Appendix 8.14 and for change in AUDIT score in Appendix 8.15.

The pattern of results was the same when analysing the data with ANCOVAs adjusting for baseline characteristics (data not shown).

Table 6.2: Primary outcome: main effects of intervention modules on change in alcohol consumption

	Mean change in alcohol consumption Units (SD)				Bayes Factors	
	Enhanced	Minimal	F	P	5 Units	3 Units
Self-monitoring and Feedback	-4.28 (13.37)	-3.33 (14.48)	0.78	0.38	0.49	0.76
Action Planning	-3.61 (12.22)	-4.01 (15.48)	0.13	0.71	0.16	0.26
Normative Feedback	-4.10 (14.93)	-3.52 (12.87)	0.30	0.59	0.34	0.54
Cognitive Bias Re-training	-4.15 (13.92)	-3.47 (13.95)	0.39	0.53	0.37	0.58
Identity Change	-3.02 (13.13)	-4.60 (14.66)	2.16	0.14	0.09	0.15

Table 6.3 Secondary outcomes: main effects of intervention modules on change in AUDIT score

	Mean change in AUDIT score (SD)				Bayes factor
	Enhanced	Minimal	F	P	
Self-monitoring and Feedback	-0.80 (2.66)	-0.68 (2.56)	0.35	0.56	0.23
Action Planning	-0.88 (2.71)	-0.61 (2.51)	1.75	0.19	0.59
Normative Feedback	-0.87 (2.68)	-0.61 (2.54)	1.60	0.21	0.54
Cognitive Bias Re-training	-0.77 (2.37)	-0.71 (2.84)	0.10	0.75	0.18
Identity Change	-0.71 (2.71)	-0.77 (2.51)	0.09	0.77	0.11

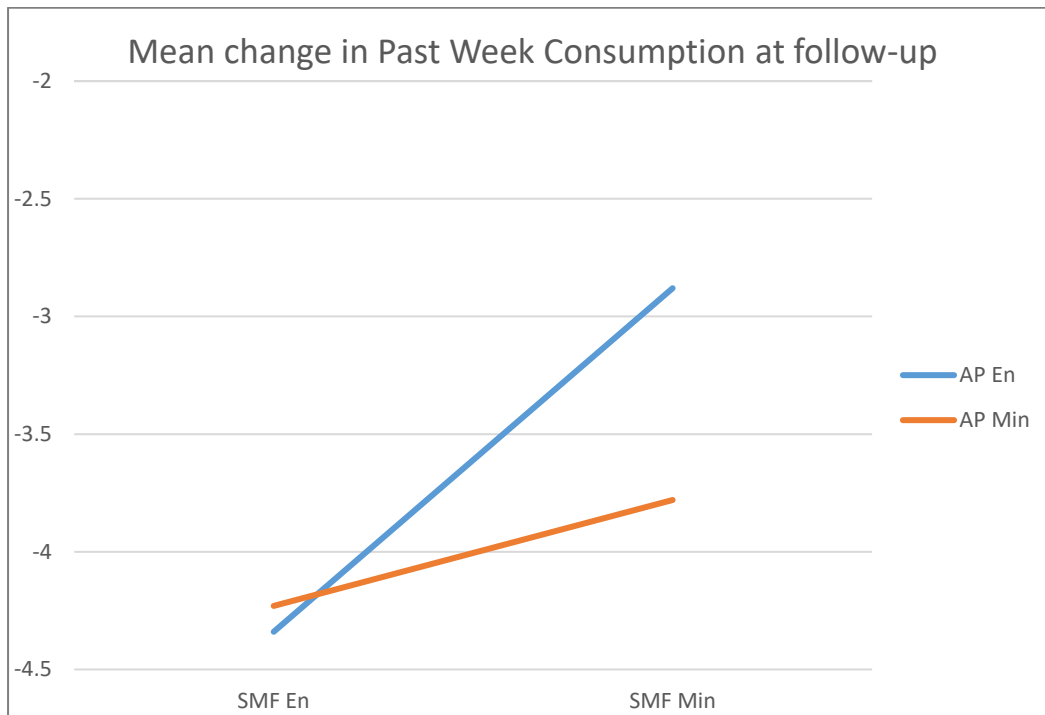
Table 6.4: Mean change in AUDIT score at follow-up

Condition	Mean change in AUDIT score, (SD)
SMF Enhanced, AP Enhanced	-1.18 (3.15)*
SMF Enhanced, AP Minimal	-0.42 (2.00)
SMF Minimal, AP Enhanced	-0.57 (2.15)
SMF Minimal, AP Minimal	-0.79 (2.92)

* $t(670) = -2.52$; $p = 0.01$, for comparison of SMF + AP enhanced compared with the other conditions.

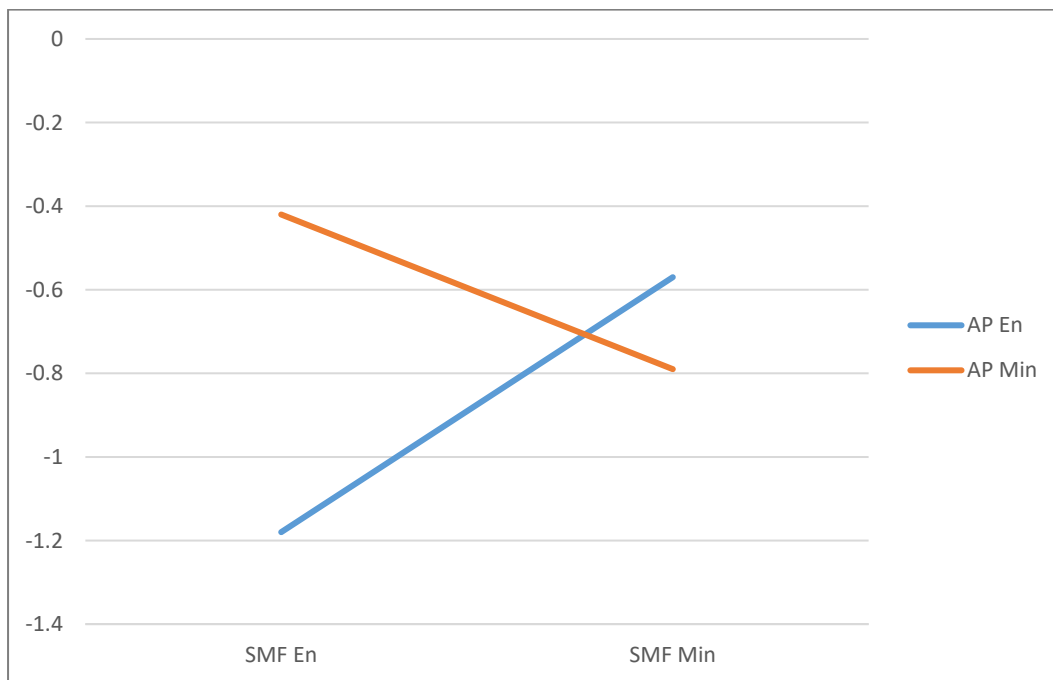
SD = Standard Deviation. SMF = Self-monitoring and Feedback, AP = Action Planning

Figure 6.2: Mean change in Past Week Consumption score at follow-up



SMF = Self-monitoring and Feedback, AP = Action Planning, En = Enhanced, Min = Minimal

Figure 6.3: Mean change in AUDIT score at follow-up



SMF = Self-monitoring and Feedback, AP = Action Planning, En = Enhanced, Min = Minimal

6.4.3 Bayes factors

As the main effects for intervention modules were not significant Bayes Factors were calculated to determine the strength of evidence for the null hypothesis. Bayes Factors were calculated for a reduction in five units, as per the power calculation for the main outcome measure, and three units, as a sensitivity analysis. Bayes Factors were also calculated for a change in AUDIT score. Bayes Factors were interpreted according to established cut-off points, where a Bayes Factor below 0.33 represents evidence for the null hypothesis, a Bayes Factor above 3.0 represents evidence for the experimental hypothesis, and Bayes Factors between those two scores indicates that the data are insensitive [484,518].

Bayes Factors for a reduction in consumption of five or three units for Self-monitoring and Feedback were 0.49 and 0.76 respectively, both of which indicate anecdotal evidence for the null hypothesis of no effect for the enhanced version of modules (Table 6.2). The Bayes Factors for a reduction in consumption of five or three units for Action Planning were 0.16 and 0.26 respectively, both of which indicate moderate evidence for the null hypothesis (Table 6.2). The Bayes Factor for a change in AUDIT score for Self-monitoring and Feedback was 0.23, indicating moderate evidence for the null hypothesis, and the Bayes Factor for a change in AUDIT score for Action Planning was 0.59 indicating anecdotal evidence for the null hypothesis (Table 6.3).

6.4.4 Secondary outcomes: Effects of the intervention modules on app usage and usability ratings

The app usage figures reported here cover the period starting when the participant downloaded the app, up to 28 days later. I.e. if a participant downloaded the app on 1st July their usage data up to and including 29th July was included but any usage data from 30th July onward was excluded.

Participants used the app a total of 7,832 times for a mean 11.7 sessions per participant and 11.6 screens per session. Sessions lasted a mean of 4 minutes, 23 seconds. Participants used the app a

mean of 8.0 different days (SD: 8.11) covering a mean period of 11.0 days (SD: 10.92). Participants given the enhanced version of the self-monitoring and feedback module used the app for a significantly greater number of sessions than participants given the minimal version ($f = 12.73$; $p < 0.001$; Table 6.5). There were no significant differences in mean number of sessions between the enhanced and minimal versions of the Action Planning module. There were no significant differences in mean length of session between the enhanced and minimal version of either module.

Table 6.5: Secondary outcomes: main effects of intervention modules on usage

	Mean number of sessions (SD)				Mean length of session (SD)			
	Enh	Min	F	P	Enh.	Min	F	P
Self-monitoring and Feedback	13.53 (15.33)	9.78 (11.66)	12.73	<0.001*	4:23 (4:34)	4:23 (4:05)	<0.001	0.99
Action Planning	11.44 (12.79)	11.87 (14.63)	0.17	0.68	4:36 (4:33)	4:09 (4:05)	1.79	0.18
Normative Feedback	12.33 (14.40)	10.98 (13.02)	1.64	0.20	4:34 (4:39)	4:11 (3:58)	1.36	0.24
Cognitive Bias Re-training	11.77 (14.36)	11.54 (13.10)	0.05	0.82	4:21 (4:21)	4:25 (4:19)	0.04	0.83
Identity Change	12.14 (13.71)	11.17 (13.76)	0.85	0.36	4:36 (4:41)	4:10 (3:56)	1.74	0.19

Enh = Enhanced, Min = Minimal. * indicates $p < 0.05$.

Participants given the enhanced version of the Self-monitoring and Feedback module rated the app as significantly more helpful ($f = 4.39$; $p = 0.04$), more satisfying ($f = 6.60$; $p = 0.01$) and were more likely to recommend the app to a friend ($f = 5.02$; $p = 0.03$) than participants given the minimal version (Table 6.6). There were no significant differences between the enhanced and minimal version of the Action Planning module on ratings of app usability, and no significant differences between both enhanced and minimal modules on the rating of ease of use. No significant interactions were found for app usage (Appendix 8.16) or usability ratings (Appendix 8.17).

Table 6.6: Secondary outcomes: main effects of intervention modules on app usability

	Helpfulness				Ease of use				Recommend to a friend				Satisfaction			
	Enh	Min	F	P	Enh	Min	F	P	Enh	Min	F	P	Enh	Min	F	P
Self-monitoring & Feedback Mean, (SD) n = 98	3.18 (0.93)	2.88 (0.96)	4.39	0.04*	3.59 (1.00)	3.46 (1.03)	1.11	0.29	3.25 (1.22)	2.79 (1.19)	5.02	0.03*	3.36 (1.00)	3.00 (0.92)	6.60	0.01*
Action Planning Mean, (SD) n = 90	3.04 (1.02)	3.04 (0.90)	0.01	0.93	3.56 (1.07)	3.50 (0.96)	0.47	0.49	3.08 (1.23)	3.00 (1.22)	0.33	0.57	3.26 (1.00)	3.14 (0.97)	1.30	0.26
Normative Feedback Mean, (SD) n = 101	3.05 (0.88)	3.04 (1.05)	0.01	0.90	3.45 (0.97)	3.62 (1.06)	0.72	0.40	2.99 (1.23)	3.10 (1.22)	0.28	0.60	3.22 (0.95)	3.17 (1.02)	0.17	0.68
Cognitive Bias Re-training Mean, (SD) n = 89	3.02 (0.98)	3.06 (0.94)	0.03	0.86	3.45 (0.97)	3.60 (1.05)	0.22	0.64	2.91 (1.23)	3.16 (1.21)	1.07	0.30	3.20 (0.97)	3.20 (1.00)	0.03	0.86
Identity Change Mean, (SD) n = 96	3.09 (0.97)	2.99 (0.94)	0.17	0.68	3.57 (1.00)	3.48 (1.02)	0.02	0.89	3.15 (1.16)	2.92 (1.28)	0.40	0.53	3.25 (0.95)	3.14 (1.01)	<0.01	0.95

Enh = Enhanced, Min = Minimal. * indicates $p < 0.05$.

6.4.5 Unregistered analyses

6.4.5.1 Effect of the app for all participants

One sample t-tests were conducted to assess the effect of the app on all participants regardless of their experimental condition (Table 6.6). There was a significant decrease in past week alcohol consumption using an intent-to-treat analysis (-3.8 units; $t = -7.09$; $p < 0.001$) and amongst responders only (-14.3 units; $t = -7.94$; $p < 0.001$) from baseline to follow-up. There was also a significant difference in AUDIT score using an intent-to-treat analysis (-0.7 points; $t = -7.36$, $p < 0.001$) and amongst responders only (-2.9 points; $t = 8.39$; $p < 0.001$) from baseline to follow-up. Participants responding to follow-up rated the app significantly above neutral (a score of '3') on 'ease of use' ($t = 6.98$; $p < 0.001$) and on 'satisfaction' ($t = 2.68$; $p < 0.01$). No significant per-module differences in change in past week consumption (Appendix 8.18) or in change in AUDIT score (Appendix 8.19) were found.

Table 6.6: Overall effect on outcome measures

Outcome measure		N	Mean (SD)	t	p
Change in past week alcohol consumption, units per week	ITT	672	-3.8 (13.93)	-7.09	<0.001
	Responders only	179	-14.3 (24.10)	-7.94	<0.001
Change in AUDIT score	ITT	672	-0.7 (2.61)	-7.36	<0.001
	Responders only	172	-2.9 (4.53)	-8.39	<0.001
Helpfulness rating		182	3.0 (0.96)	0.62	0.54
Ease of use rating		178	3.5 (1.01)	6.98	<0.001
Recommendation rating		178	3.0 (1.22)	0.43	0.67
Satisfaction rating		178	3.2 (0.98)	2.68	<0.01

ITT = Intent-to-treat analysis

6.4.5.2 Overall effect of app 'intensity'

The 'intensity of the app was defined in the following way: 'High intensity' participants were those who received four or more of the 'enhanced' versions of intervention modules (n = 126); 'Low intensity' participants were those who received one or no 'enhanced' versions of intervention modules (n = 126). Intensity was assessed in a one-way ANOVA (Table 6.7). Participants who received a 'high intensity' app used the app for a significantly greater number of sessions (f = 4.21; p = 0.04) and rated their satisfaction with the app significantly higher than those who received a 'low intensity' app (f = 4.35; p = 0.04). The finding that participants who received a 'high intensity' app used the app for a greater length of time per session did not quite reach statistical significance (f = 4.21; p = 0.051).

Table 6.7: Post-hoc analysis of effect of intensity of app on outcome measures

Outcome measure	N	Mean score (SD)		F	p
		High intensity	Low intensity		
Change in PWC (Units per week)	252	-4.3 (13.50)	-4.4 (16.49)	<0.01	0.96
Change in AUDIT score	252	-1.0 (2.41)	-0.5 (2.58)	2.60	0.11
Number of sessions	252	13.4 (14.46)	9.8 (13.14)	4.21	0.04
Length of time per session	252	4:35 (4:20)	3:44 (2:27)	3.83	0.051
Helpfulness rating	64	3.1 (0.97) n = 36	2.8 (1.08) n = 28	1.70	0.20
Ease of use rating	62	3.5 (0.99) n = 34	3.4 (1.10) n = 28	0.03	0.88
Recommendation rating	62	3.1 (1.23) n = 34	2.6 (1.26) n = 28	2.36	0.13
Satisfaction rating	62	3.4 (0.95) n = 34	2.8 (1.06) n = 28	4.35	0.04

PWC = Past week consumption.

6.4.5.3 Mediation analysis

I explored whether the effect of enhanced Self-Monitoring and Feedback on change in AUDIT score amongst users assigned to the enhanced Action Planning module was mediated by their greater app use (indicated by number of log-ins). In a model including assignment to the Self-Monitoring and Feedback module and app usage, app usage was significantly related to the change in AUDIT scores ($B = -0.05$, 95% CI = -0.07 to -0.03, $p < 0.001$) but there was no longer evidence of the effect of enhanced Self-Monitoring and Feedback module ($B = -0.44$, 95% CI = -1.01 to 0.13, $p = 0.13$), and a Sobel test confirmed the mediation by app usage ($z = -2.21$, $p = 0.03$). The potential mediation of satisfaction ratings could not be calculated as data were only available from the 27% of participants who completed follow-up measures.

6.5 Discussion

Participants using an alcohol reduction app drank three to four fewer units of alcohol and had a marginally lower AUDIT score at one-month follow-up compared to baseline, regardless of group allocation. There were no significant differences in the change of amount of alcohol consumed or AUDIT score for participants given an enhanced or minimal version of a Self-monitoring and Feedback module or the Action Planning module. However, there was a significant synergistic interaction: the Self-Monitoring and Feedback and Action Planning modules resulted in a lower AUDIT score when both were in their enhanced condition; when either or both were in a minimal condition, no significant effect was detected. Significant differences in app use and usability ratings were found; participants given the enhanced version of the Self-monitoring and Feedback module used the app more often, rated the app more helpful and satisfying, and were more likely to recommend the app to a friend, than participants given the minimal version of this module. A mediation analysis found that evidence of the effect of Self-Monitoring module among users assigned to Action Planning enhanced on AUDIT outcomes was mediated by increased use of the app.

The synergistic interaction between modules on a change in AUDIT score is supported by evidence. Control Theory proposes that self-monitoring, feedback and action planning are important if any distance between one's current position and a goal is to be detected and reduced [12]. Previous findings from alcohol interventions [281], other health behavioural domains [13,14] and a meta-analysis of the effect of self-monitoring on goal attainment [325] have found the inclusion of more Control Theory congruent BCTs to be associated with improved outcomes. The role of action planning is further supported by a study of the BCTs in alcohol DBCIs, which found that two BCTs that help people identify practical ways of reaching their drinking reduction goals: 'Behaviour substitution' and 'Problem solving', were associated with intervention effectiveness [Chapter 3]. Taken together, these findings suggest that alcohol DBCIs may be more effective if they provide goal setting, self-monitoring, feedback and action planning; and that a form of action planning that provides guidance and direction about how users can overcome obstacles to their drinking reduction goals may further increase effectiveness. The mediation result suggests that future refinement of the Self-monitoring and Feedback module should focus on its ability to increase use of the app.

The finding of no main effects for Self-Monitoring and Feedback or the Action Planning module was not as predicted. A considerable body of evidence exists for the effectiveness of the BCTs of self-monitoring, feedback, and action planning [Chapter 4], and independent effects were expected. Potential explanations for why these BCTs weren't found to be effective in the app may relate to issues of assessment reactivity and ongoing self-monitoring, or low use of the module.

6.5.1 Assessment reactivity and ongoing self-monitoring

The absence of a significant independent effect of the enhanced Self-monitoring and Feedback module may be a consequence of an active control group. All participants were required to complete the AUDIT questionnaire at baseline. The tendency of participants to change their behaviour in response to being monitored is known as the 'Hawthorne effect' in psychology [519]. The tendency

of participants to change their behaviour in response to monitoring themselves is known as 'assessment reactivity' in the alcohol literature [520]. Assessment reactivity usually refers to the effect of baseline measures of assessment, such as the AUDIT questionnaire, on subsequent reductions in consumption. Control groups who receive baseline assessment often report reduced consumption at follow-up (e.g. [521,522]). A meta-analysis of trials that evaluated assessment reactivity experimentally found that participants given alcohol-related assessments reduced their consumption of alcohol by a mean 13.7 grams per week more than participants given fewer or no assessments, although this finding did not quite reach statistical significance (95% CI: -0.17 to 27.6; $z = 1.94$; $p = 0.053$) [520].

All participants were also prompted to complete their drinking diary each morning. Ongoing self-monitoring has been associated with small-to-medium-sized improvements in goal attainment [325] and is frequently associated with improved weight and diabetes management (e.g. [373–375]). There appears to be less evidence about ongoing self-monitoring in the alcohol literature, but the evidence that exists accords with other findings. Regular reporting of alcohol consumption has been associated with reduced consumption over the two-year period of an intervention [376]. Students assigned a set of drinking questionnaires at baseline, three, six and 12 months reduced their AUDIT score and had lower peak blood alcohol content (BAC) levels at follow-up than controls, who were only assigned questionnaires at 12 months [523].

The potential for this study to detect an independent effect of the enhanced Self-monitoring and Feedback module may, therefore, have been limited by assessment reactivity and ongoing self-monitoring. It is doubtful that assessment reactivity could have been avoided; in order to evaluate the effect of the app on harmful and hazardous drinkers it was necessary to assess a user's level of drinking at baseline. However, the limitation introduced by ongoing self-monitoring could perhaps have been avoided.

The primary reason all participants were given the opportunity to self-monitor their consumption and prompted to complete their daily diary was to promote engagement with the app. Users want and perhaps expect an alcohol reduction app to include self-monitoring; it was the most commonly included BCT in alcohol reduction apps available in the UK [Chapter 2], and was a feature considered highly important by users of a web-based alcohol intervention [312], users of an alcohol use disorder app [490], users of other alcohol reduction apps [491], and users of this app [Chapter 5]. An app without a self-monitoring module is likely to be chosen and used substantially less often than one which provides the BCT; which could make trial recruitment more difficult and may result in an unrepresentative sample.

All participants were prompted to complete their daily diary because many elements within modules (feedback about goals and consumption, parts of the Identity module, the Action Planning module) function optimally with repeated use. The Cognitive Bias Re-training module is likely to benefit from repeated use [524]. The prompt was intended to encourage participants to open the app, in the hope that use of other modules might then naturally occur. Usage data suggests this method was successful. However, it is possible that prompting people to self-monitor on a daily basis had a reactive effect on participants in the control condition, which would have made it harder to detect an effect of enhanced Self-monitoring and Feedback.

The second reason all participants were prompted to complete their daily diary was to calculate past week consumption from in-app drinking records. A decision was later made – before the start of the trial – to complete follow-up measures via email or in-app questionnaire instead. At this point it would have been preferable to review the purpose of the daily diary prompt to determine if all participants should still receive it, but such a review did not take place. This omission highlights a difficulty of the iterative development common to technology products [188]. Numerous changes were made to the initial specification of the app over the course of the 20 month period of its development. Feedback from users or from the research team frequently illustrated ways in which

these modules could be improved to provide a better user experience, be more engaging, or improve the experimental design. Occasionally these improvements resulted in changes to elements that counteracted or nullified their previous purpose, as the addition of an emailed questionnaire did to the outcome measure purpose of the daily prompt. The method recommended for future app development is to carefully record the purpose of all functional elements and the rationale for all decisions, and to review these records before changes are made.

6.5.2 Low use of the Action Planning module

Usage data indicates low use of the Action Planning module. Users allocated to the enhanced version of this module were not significantly more likely to log-in than those receiving the text-only minimal version (11.44 vs 11.87 sessions) or spend time on the app (4:36 vs 4:09 minutes).

Moreover, only 44 of the 336 participants assigned to Action Planning enhanced set an implementation intention within the app, and those 44 participants only created 77 implementation intentions in total. Other functionality within the module was also used infrequently, total use of Action Planning was less than a third that of any other module.

Implementation intention interventions often report high levels of non-compliance. A third of participants in a physical activity trial, half the participants in an alcohol reduction trial, and 99% of participants in a trial of multiple health behaviours declined to create an implementation intention [414,525,526]. Implementation intentions that are specific and precise are more likely to promote goal attainment [112,525], but over 80% of participants in a sexual health study created implementation intentions deemed to be poor quality [527]. These results were found in studies where participants were explicitly asked to create an implementation intention. This study adopted a less directive approach: it made the module available to participants and only recommended implementation intentions be set. This decision was taken so as to not overwhelm users with compulsory tasks when first using the app, as that might increase the already high rates of attrition

associated with first use [467]. Low use of this module suggests that future interventions may want to adopt a middle ground and encourage participants to set an implementation intention shortly after their first use of the app.

6.5.3 Heavy drinking sample

Our sample included many people with very high levels of drinking. The mean number of units consumed in the past week at baseline was 40, almost three times the UK Government's recommended limit of 14 [32]. The mean AUDIT score at baseline was 19, on a scale in which 20 or more indicates potential dependence on alcohol [31].

Guidance recommends that people who score 20 or over on the AUDIT should be referred to a specialist for further evaluation [31], and this app adopted that guidance (Appendix 8.20). Even so, participant characteristics demonstrate that large numbers of people with potentially problematic alcohol use will turn to an app for help. It is unclear whether they do so in conjunction with specialist help, but the stigma associated with admitting excessive alcohol consumption [156,157,528] and the importance of anonymity to users of DBCIs [165] suggests that it may be an only, or the first, port of call.

This app was aimed at hazardous and harmful drinkers, its use by people with a potential alcohol-use disorder indicates the need for an evidence-based alcohol reduction app aimed at helping people who may require, but be reluctant to access, specialist help. Additionally, if guidance is to be followed and this sample is representative, all alcohol reduction apps may need to recommend that people indicated to have a potential dependence on alcohol be referred to specialist help. Experimental work on how to do this effectively appears important to conduct.

6.5.4 App usage and usability ratings

The app was used frequently (mean: 11.7 sessions per participant and 11.6 screens per session) and for a considerable amount of time (mean: 4 minutes, 23 seconds per session). Standardised measures for reporting the use of app interventions do not seem to have been adopted, but use of *Drink Less* appears broadly comparable to app-delivered interventions for smoking [529] and alcohol [277], as well as industry benchmarks for use [530]. Whilst two alcohol app interventions have recorded higher levels of engagement, their sample consisted of people leaving residential treatment for alcohol dependence [276] or people in treatment for HIV [278]; a sample whose motivation to use an app may, therefore, have been greater than the participants in this study, who downloaded the app unbidden.

The Self-monitoring and Feedback module was used particularly often, four times as often as the next most-used module: Normative Feedback. A portion of this use can probably be accounted for by participants responding to the prompt to complete their drinking diary. However, participants given the enhanced version of Self-monitoring and Feedback used the app for a greater number of sessions, rated the app more helpful and more satisfying, and were more likely to recommend the app to a friend, than participants given the minimal version. This suggests that it was the additional features within enhanced Self-monitoring and Feedback that participants found engaging.

The enhanced Self-monitoring and Feedback condition differed from the minimal condition in that it allowed participants to monitor the consequences of their consumption, and provided feedback about consumption, the consequences of consumption (amount consumed, calorie intake, spend on alcohol, impact of heavy drinking on next-day mood, clarity, productivity and sleep quality) and performance against goals. Self-monitoring and Feedback enhanced therefore contained the BCTs of: 'Self-monitoring of behaviour', 'Self-monitoring of outcomes of behaviour', 'Feedback on behaviour', 'Feedback on outcomes of behaviour', 'Salience of consequences', 'Information about

emotional consequences', 'Review behaviour goals', 'Discrepancy between current behaviour and goal', 'Social reward', 'Self-reward' and 'Non-specific reward' (participants received positive feedback when entering drinks, recording no drinking days and when setting and achieving goals). A review of the BCTs used in alcohol DBCIs found that 'Feedback' and 'Salience of consequences' were frequently used; Self-monitoring was often used, but the other BCTs were rarely used [Chapter 3]. This combination of BCTs was chosen in order to give participants a comprehensive range of self-monitoring options and a comprehensive amount of feedback. Usage and usability ratings for the app suggest that this method had a positive effect on participant engagement.

Overall ratings of the app suggest the app was positively received, but mean scores were not greatly above the median point of 3 in a 1-5 scale. Online reviews tend to skew positive [531] and it is perhaps not unreasonable to expect that people who responded to follow-up were more likely to have a favourable view of the app. With this in mind, the slightly positive ratings reported here may disguise overall dissatisfaction with the app.

A degree of dissatisfaction is perhaps unsurprising in a factorial RCT conducted entirely within an app, where most participants will be assigned to at least one control condition. Reviews left on the Apple App Store and correspondence to the research team indicated that a number of people assigned to Self-monitoring and Feedback minimal were disappointed not to receive feedback about the consumption they had logged. Negative reviews could affect rates of trial recruitment and dissatisfied participants may also be less likely to respond to follow-up. However, attempts to ensure all participants are satisfied in factorial RCTs may result in limitations arising from active controls. It is therefore recommended that app developers focus on ensuring that the enhanced version of modules provide the most satisfying user experience, that user expectations about what they'll receive be managed, and that some dissatisfaction be seen as inevitable. In addition, the satisfaction ratings reported here could be interpreted as a relative assessment of this app's ability to meet user

needs, against which other behaviour change apps undergoing factorial evaluation could perhaps be compared.

6.5.5 Strengths and limitations

This study appears to be the first to evaluate the effectiveness of an alcohol reduction app on a population of self-directed treatment-seekers. Participants were not recruited for a trial and then given an alcohol reduction app, they sought out an app and were then recruited for a trial. This sample is, therefore, representative of people who wish to reduce their excessive alcohol consumption by way of their own resources. Understanding what techniques are effective for them may ensure that health behaviour change apps are increasingly able to fulfil their potential to help people self-manage their health. This study also appears to be the first to evaluate the effectiveness of individual modules of behaviour change techniques on reducing consumption in an alcohol DBCI. Greater understanding of the mechanisms of action in interventions is essential if more effective interventions are to be developed [8,320]. More effective interventions are needed if the health, economic and societal costs of alcohol are to be reduced. Thirdly, the use of a factorial design allowed multiple simultaneous evaluations to be performed with a relatively small sample. Undertaking these trials consecutively would have taken considerably more time, such that by the end of the study any initial findings may have been made obsolete by the rapid rate of technological development [532]. Lastly, the app continues to be downloaded on a regular basis, an average of 40 new users a day since the trial was complete. The finding that all trial participants had reduced their consumption suggests that the app may provide ongoing help to new users. The number of new downloads also indicates a ready source of participants for any future trial which develops upon the work started here.

However, reductions in consumption could partly be accounted for by regression to the mean [533]. The motivation to seek out an alcohol reduction app may be greater at times when drinking is

particularly severe. Levels of consumption that are unusually high tend to reduce to more usual levels without intervention. High levels of baseline consumption combined with high rates of attrition can mask the effects of an intervention that uses an intent-to-treat analysis. Attempts to increase follow-up rates (described in section 6.3.4, Procedure, above) were relatively unsuccessful: 73% of participants did not respond to follow-up and were treated as drinking at baseline levels; levels which regression to the mean suggests may have been unusually high. The 27% of people who responded to follow-up would have needed to report a large effect to overcome the much larger number considered to be treatment failures. DBCIs commonly experience high rates of attrition [181] and users often do not use an app more than once [467]. High rates of missing data reduces the ability to make accurate inferences from trial findings [534]. Better ways of increasing follow-up and different ways of treating missing data may be necessary if the true effect of a digital intervention is to be identified. Secondly, a factorial design can result in modules with conflicting requirements. For example, some modules were designed for repeated use. To encourage repeated use participants were invited back to the app via a daily prompt to complete their drinking diary. This prompt may have had a reactive effect on participants in self-monitoring minimal, which made assessing the effect of the enhanced condition more difficult. Careful design of modules is necessary if such conflicts are to be avoided. As noted above, the lack of an independent effect of the enhanced version of modules may be a consequence of assessment reactivity, ongoing self-monitoring or low intervention use. A final limitation is that the synergistic interaction was identified only on the secondary outcome of change in AUDIT score but not on the primary outcome of change in past week consumption. Therefore, this result should be treated with some caution.

6.5.6 Conclusions

Users of an alcohol reduction app reported less alcohol consumption and a lower AUDIT score at one-month follow-up, but there were no significant differences in outcomes between those who received enhanced versions of the Self-monitoring and Feedback or Action Planning modules

compared with the respective minimal versions. An interaction indicated that there was effect of each module on the reduction in AUDIT score that depended upon the enhanced version of the other module being available. The Self-monitoring and Feedback module also increased measures of app usability and engagement. Both modules should be evaluated in their enhanced conditions against a minimally active or usual care control in a future RCT.

7 General discussion

7.1 Summary

The health, societal and economic costs of excessive alcohol consumption mean there is an urgent need for effective alcohol reduction interventions [46]. Brief interventions delivered in primary care have an established record of effectiveness [4], but doctors appear reluctant to provide them and patients seem reluctant to seek them [150,156]. Digital behaviour change interventions (DBCIs) are usually conducted without physician involvement. Their anonymity and convenience may make them more attractive to patients [160,165]. Meta-analyses have concluded that DBCIs for alcohol reduction produce small but clinically meaningful reductions in alcohol consumption at a population level (e.g. [5–7]). Almost all published alcohol DBCIs have been conducted on web sites [Chapter 3]. Apps are a similar modality, but their widespread acceptance, portability, and increased technological capacities, may allow them to provide better support to a greater number of people. Healthcare apps are popular [228]; however, the vast majority are developed without reference to evidence or theory, and their effectiveness remains to be proven [Chapter 1].

The research reported in this thesis used the Multiphase Optimisation Strategy [475] for developing complex interventions and reflected an early phase of the method by systematically identifying and evaluating promising modules. Modules were selected for evaluation in a process that involved two studies and a review of the literature. The first study found that the majority of alcohol-related apps available in the UK were designed to promote alcohol consumption, fewer than 15% had an alcohol reduction focus, and alcohol reduction apps tended to make little use of behaviour change techniques (BCTs) or theory [Chapter 2]. The second study found that DBCIs for alcohol reduction made little use of BCTs with an evidence-base of effectiveness, such as self-monitoring and goal setting [Chapter 3].

A review of the literature identified Control Theory as providing a potential theoretical basis for the intervention. Control Theory proposes a process of goal attainment involving: self-monitoring behaviour, using feedback to review one's current position in relation to a goal and action planning to determine how any discrepancy between the two can be reduced [12]. Control Theory congruent BCTs are supported by a considerable body of evidence [Chapter 4] and were identified by alcohol and behaviour change experts as the four BCTs most likely to be effective in an alcohol reduction app [16].

The two modules evaluated in this thesis – Self-monitoring and Feedback and Action Planning – were therefore selected on the basis of theory and evidence. Self-monitoring was combined with Feedback because these two BCTs are often delivered together and have been found to augment each other [383,384]. Goal setting was included in the app but not selected for evaluation for three reasons: 1) the ability to set goals was judged likely to be crucial for user engagement, 2) there is already good evidence for the effectiveness of the technique [128] and sufficient reason to include it in a complex intervention without further evidence, and 3) Control Theory suggests that the effectiveness of the Self-monitoring and Feedback and/or the Action Planning modules may depend on at least one goal being set [12]. There was some reason to select 'Credible source' for evaluation [Chapters 2 and 3] but the evaluation was necessarily planned to take place under the auspices and branding of UCL and NIHR SPHR, with transparent information about the investigators. Therefore, all respondents would have received some dose of the BCT 'Credible source' and the scope to detect an effect over and above this may have been limited.

User engagement with *Drink Less* was promoted by conducting two usability studies [Chapter 5]. Studies of first time and experienced users found that both groups wanted an alcohol reduction app to be easy, rewarding and beneficial to use. Participants described an easy-to-use app as one that reduced user burden, offered ongoing help and was

aesthetically pleasing. A rewarding and beneficial app was described as one that demonstrated credibility, provided positive reinforcement and gave feedback about progress. Findings from this study resulted in a series of improvements made to the app in advance of its evaluation.

The final study conducted for this thesis was a factorial randomised control trial that evaluated the effectiveness of the 'enhanced' Self-monitoring and Feedback and Action Planning modules on reducing measures of alcohol consumption [Chapter 6]. The hypothesis that enhanced versions of modules would have independent effects over and above the minimal versions was not supported. Nonetheless, the finding that enhanced Self-monitoring and Feedback increased measures of app usability and the finding of an interaction between enhanced Self-monitoring and Feedback and enhanced Action Planning on a reduced AUDIT score at follow-up, indicates that both modules should be considered for evaluation against a minimally active control in their enhanced conditions in a future RCT. In addition, the finding of an interaction between enhanced Self-monitoring and Feedback and enhanced Action Planning on reduced AUDIT score provides further evidence for including more Control Theory congruent BCTs in behaviour change interventions.

7.2 Strengths

This thesis adds to the scientific literature about the development and evaluation of behaviour change apps by describing the rigorous process that led to the selection of modules and the time- and participant-efficient method used to evaluate their effectiveness. *Drink Less* was theory-driven and evidence-based, sought to understand and meet user needs, adopted good practices from industry, and used a method of evaluation specifically designed for DBCIs [475]. Methodologies for developing and evaluating apps, such as the one described in this thesis, may allow apps to fulfil their potential to provide a cost-

effective way of helping large numbers of people reduce their alcohol consumption. Such methodologies may also be useful for apps aimed at other health behaviour change domains.

One of the challenges presented when developing a behaviour change app is that it will exist in an environment where many similar apps are available [Chapter 2]. Understanding the type and composition of existing apps, as the first study sought to do, is a strength of this thesis, as it demonstrated what BCTs were commonly used and where gaps in provision might lie. Commonly used BCTs may suggest app functionality that users want or expect; identifying and meeting gaps in provision may give users a reason to choose the app in preference to others.

The rigorous process that led to the selection of modules for evaluation is a strength of this thesis. Alcohol DBCIs were examined for the BCTs they contain and for associations between BCTs and intervention effectiveness [Chapter 3]. Alcohol and behaviour change experts were consulted for their views on BCTs they thought would be effective [16]. Relevant published scientific literature was searched for evidence for or against the top four BCTs these experts had chosen and for theory that might explain how a particular combination of BCTs could be effective [Chapter 4].

A focus on understanding and meeting user needs is a strength of this thesis. User needs for an alcohol reduction app were identified by reviewing the usability literature, examining existing apps and conducting usability studies [Chapter 5]. DBCIs tend not to be used repeatedly, and attrition is most severe during early stages of use [467]. Conducting two usability studies amongst 1) first time and 2) experienced users allowed issues with initial use and with repeated use to be identified and addressed. Findings about the specific ways in which participants who were engaged in self-directed behaviour change wanted an

alcohol reduction app to be easy and rewarding to use, may help other alcohol DBCIs, and DBCIs more generally, promote engagement with the intervention.

The development of *Drink Less* was informed by good practices used by professional app developers. Apple's human interface guidelines were consulted, user experience experts' views were studied and well-established app development methodologies were employed [Chapter 6: 'The build process', section 6.3.10.6]. Industry possesses a considerable amount of tried-and-tested knowledge about how to create apps that meet user needs. Making use of this knowledge can allow scientifically-driven apps to compete in the marketplace.

The final study conducted for this thesis is the first to my knowledge to evaluate the effectiveness of an alcohol reduction app on a general population sample engaged in self-directed behaviour change and to evaluate the effectiveness of individual modules of BCTs on reducing consumption [Chapter 6]. Its finding of a significant interaction between Self-monitoring and Feedback enhanced and Action Planning enhanced on a reduced AUDIT score at follow-up provides further evidence for the effectiveness of including more Control Theory congruent BCTs in behaviour change interventions [13,14,325] and suggests that alcohol interventions may be effective if they allow people to set goals, monitor consumption, receive feedback about progress and create action plans.

Lastly, the app's ongoing presence in the Apple App Store and its positive reception amongst users ensures a ready source of new participants for future trials.

7.3 Limitations

A limitation of studies that specify interventions only by BCTs [Chapter 2 and 3] is that recording a BCT as present or absent does not take into account the 'dose' of that BCT [315]. A BCT's effectiveness is likely to be influenced by the frequency, intensity and form in which

it is delivered. Form may be particularly critical in digital interventions where different implementations (different language, graphic design or usability) could have a considerable effect on the degree of user engagement [366]. In order to assess a BCT's effectiveness it may be necessary to develop methods to measure its 'dose' [316,367]. A second limitation of these studies may be that the incomplete reporting of intervention content [365] may have resulted in BCTs being incorrectly coded as present or absent. Thirdly, failure to identify evidence for associations should not be taken as evidence for the null hypothesis of no effect, as both studies coded a large number of BCTs against a modest sample size and many BCTs were not present frequently enough to be included in analyses. More detailed reporting of intervention content is required if BCTs and the mechanisms of action of an intervention are to be accurately identified.

In the study of BCTs in alcohol DBCIs [Chapter 3], a limitation concerning the statistical analyses was identified. The relationship described by a meta-regression is an observational association across trials, and any identified association with one characteristic of the trial may reflect a true association with other correlated characteristics. Whilst issues of multicollinearity were not found to be present in the evaluation of BCTs in DBCIs, caution should be taken when interpreting the coefficients directly [364]. The finding that 'Behaviour substitution' was effective should be treated as preliminary, as the BCT was only used in four trials, three of which were conducted by the same research group using the same implementation. Greater understanding of the effectiveness of this BCT, and that of 'Problem solving' and 'Credible source', in other domains and interventions is required to support the generalisability of these findings.

A limitation of the usability study concerns the representativeness of the sample [Chapter 5]. Our intended user base was harmful and hazardous drinkers who downloaded the app incidentally. All usability study participants were classified as drinking at harmful and

hazardous levels, but most participants in the first study were actively recruited from a convenience sample and therefore, their views may not represent those of people who voluntarily seek out and choose an app. A second limitation concerned the analysis. Researchers with greater experience in qualitative analyses and/or the evidence on alcohol reduction may have reached additional and/or different conclusions. Care should be taken when generalising these findings: this was a study of a particular alcohol reduction app, findings may not apply to other behaviour change apps.

The overall reduction in alcohol consumption found in the RCT is consistent with regression to the mean [533]. Unusually high levels of baseline consumption, combined with high rates of attrition, can mask the effects of an intervention that uses an intent-to-treat analysis. Better ways of increasing follow-up are likely to have increased the robustness of findings; for example, response rates could be increased with text reminders for follow-up [535,536] and financial incentives for completion [537].

Complex interventions with multiple modules can result in modules with conflicting requirements. For example, in order to promote engagement with *Drink Less*, all participants were prompted to complete their drinking diary each day. Ongoing self-monitoring has been associated with reduced alcohol consumption [523], and control groups who merely complete assessment measures at baseline have reported reduced alcohol consumption at follow-up (e.g. [376,523]). It is possible that using the prompt to encourage people to return to the app may have resulted in a reduction in consumption in participants assigned to the Self-monitoring and Feedback minimal condition, which made determining the effect of the enhanced condition more difficult. Documenting the purpose of all functional elements within a DBCI and the rationale for all decisions, and reviewing this documentation before making changes, may help such conflicts be avoided.

A limitation of the thesis as a whole is that iterations to the app were restricted in number. Although some modules went through multiple changes before they were launched and all modules were amended in response to feedback from the usability study, more iterations are likely to have further improved the app.

7.4 Implications and future research

This research has demonstrated considerable demand for alcohol reduction apps. *Drink Less* is currently being downloaded more than 1,200 times a month, despite it being available only in the UK and only for Apple phones. Rates of download have increased over the course of the app's 18-month presence in the App Store and are likely to accelerate now that all users are given the enhanced version of all modules. The majority of negative user reviews referred to the absence of feedback. By giving all users the Self-monitoring and Feedback enhanced module it is likely that the app will receive better reviews, which may lead to more downloads [291,482].

Future improvement of the app may benefit from the adoption of an iterative approach to its development [538]. An iterative approach is one that makes changes to existing code and evaluates the effect of those changes on outcomes, using the previous version of the app as the comparator [539]. Iterative approaches are considered central to the design of a technology [188]. Their use in DBCIs may promote understanding of the mechanisms of action of an intervention. Greater understanding of which individual BCTs, which combinations of BCTs and which implementations of BCTs are associated with positive outcomes and/or engagement is needed if more effective interventions are to be developed [8,320]. Investigating the mechanisms of action of an intervention can be more accurately achieved with iterative changes to an existing app, where variables can be controlled, than in studies that compare one app to another.

Iterative approaches have at least two practical advantages. Firstly, incremental costs of making changes to modules or building new modules are expected to be lower than the initial cost of building the app. Secondly, well-built apps that follow best practices for achieving a high ranking in the app store search results (for example by careful selection of keywords and the creation of an app that receives positive user reviews [292,481,482]) would benefit from an ongoing source of new participants, which makes for rapid trial recruitment and may allow for multiple trials to be conducted each year.

One disadvantage of an iterative approach is that it is perhaps unrealistic for a single research team to conduct more than a handful of trials with their accompanying publishing requirements in a year. To resolve this, instead of conducting separate trials, changes to the app could be considered a single trial of multiple stages. This approach is similar to the refining phase of the Multiphase Optimisation Strategy (MOST) [475], which first simultaneously evaluates multiple intervention components (modules) in order to determine those that should be included in a trial, and then refines the implementation of the chosen modules into a final version evaluated against a usual care or minimal control. The method suggested here sees refinement as ongoing, does not consider there to be a 'final' version and treats usual care as the existing version of the app. Changes to the implementation of modules, or entirely new modules, would be evaluated against the results that have so far been achieved; an iteration of *Drink Less* would evaluate against the alcohol outcomes reported in Chapter 6 of this thesis, for example. Changes that result in improved outcomes would be retained and the next version of the app would test against those outcomes. At any point the current version could be compared against different types of treatment, but otherwise, the trial would continue indefinitely.

Iterative approaches to development appear uncommon in alcohol DBCIs. Some web interventions, such as BASICS, have been amended for use in different settings or used as a

base upon which other interventions have been built (e.g. [400,540]). A few BCTs, 'Social comparison' for example, have been evaluated in different formats and populations (e.g. [541,542]). At least one web intervention, downyourdrink.org.uk, has been amended since launch [312]. However, these appear to be the exceptions; the majority of alcohol DBCIs contain heterogeneous content that limits understanding of their mechanisms of action (Chapter 3, [5,207,208,210–212]), once built they are usually not developed upon and there appears to be little published evidence about the effect of iterative changes to an intervention.

As an iterative approach is uncommon, securing funding and publishing findings may prove challenging. Determination would need to be made of when to publish. Journals may need to be persuaded that that reports of small changes are worthy of publication. Alternative dissemination routes may need to be developed, perhaps a dedicated project website that publishes results as they are found and encourages its users to perform peer review.

Other methods are possible. All code and content for *Drink Less* has been made open source (Appendix 8.31), meaning any research team could take the app without cost or restriction and create a separate app to test their hypotheses. However, multiple similar apps could result in a distribution of users that makes recruitment harder for any individual app, and these apps are likely to include additional variables that would make determination the mechanisms of action more difficult. Alternatively, other research teams could use *Drink Less* as a platform. Rather than create a separate app, these researchers would make and evaluate changes to the existing app. Multiple research teams working on the same app would allow multiple experiments to be conducted, but organisational issues, such as how to manage multiple trials with potentially conflicting requirements, would need to be addressed. A suggested method for using the app as a platform in a way that addressing these issues can be found in Appendix 8.33.

Whilst challenging, an iterative approach to development would allow behavioural science to take greater advantage of the opportunities presented by apps. Iterative approaches and ongoing evaluations are valued in professional app development because they provide accurate understanding of which changes result in improved outcomes to their measures of interest [543]. A behaviour change app that develops iteratively is likely to result in a more effective app for its users and more detailed understanding of what behaviour change techniques, in which combination and which implementation, change behaviour for a particular population.

One urgent avenue of enquiry for digital interventions is how to increase engagement. Whilst engagement with *Drink Less* was comparable to other app interventions and industry benchmarks [Chapter 6], modules intended for repeated use were not often used repeatedly. This was particularly true of the Self-monitoring and Feedback module. A third of participants given Self-monitoring and Feedback enhanced didn't create any drinking records; those who did created a mean of 10, the mode was 1. Feedback was presented to users at the end of each week and was intended to show participants their progress toward their drinking reduction goals. Control Theory suggests that when the rate of progress toward a goal is deemed acceptable, positive affect is generated and further investment is made toward goal attainment [133]. Data indicate that few participants entered sufficient records for this purpose of feedback to be realised.

Findings from the usability study suggest that engagement can be increased by making use of an app more beneficial and rewarding [Chapter 5]. The app might be more beneficial if it included the two BCTs found to be effective in alcohol DBCIs: 'Behaviour substitution' and 'Problem solving' [Chapter 3]. Both these BCTs help people identify specific ways of overcoming obstacles and suggest that people engaged in self-directed behaviour change

value guidance and benefit from help determining the practical solutions they can take to the goal attainment problems they face.

The app could be made more rewarding by reducing the data input burden. For example, the timeline followback procedure has demonstrated accurate past week recall of drinking behaviour [507]; this suggests that users may only need to be prompted to complete a drinking diary on a weekly basis, rather than daily, as the app does now.

Numerous other changes to increase engagement are possible. These changes might fruitfully concentrate on presenting different ways of positively reinforcing change and making salient the beneficial outcomes that have been achieved from that change, as these approaches are theorised to promote prolonged goal pursuit [141,460] and may meet the needs of users identified in the usability study [Chapter 5].

The Action Planning module could be changed to meet recently published recommendations from Implementation Intentions experts [524]. These include 1) helping people identify their goal(s) and obstacles that may prevent their attainment before plans are developed, 2) reinforcing the link between cue and response, perhaps by using the app's built-in GPS to automatically trigger a reminder of the plan when a user arrives at a pre-determined location, and 3) investigating the effect of different ways of specifying plans, for example by varying the number and/or timing of reminders.

Our sample included a substantial number of people ($n = 312$; 46%) whose AUDIT score of 20 or more indicated a possible dependence on alcohol. *Drink Less* followed guidance [31] and recommended that these users contact their GP for further support (Appendix 8.20). The effectiveness of this recommendation is unclear. Future research may be able to determine how best to direct app users with a potential dependence on alcohol to more intensive help.

For example, in addition to the messages given at baseline, *Drink Less* could check for changes in consumption amongst users deemed to be at risk. If no positive changes were detected after a month, a second message could gently suggest that the app may not be suitable for them and that their doctor may be able to provide the help they need.

7.5 Conclusion

An evidence-based and theory driven app can help people reduce their consumption of alcohol. The interactive effect of the enhanced Self-monitoring and Feedback and Action Planning modules on AUDIT score make both modules suitable candidates for inclusion in a version of the app to be evaluated against a minimal control. The effectiveness of the enhanced Self-monitoring and Feedback on measures of usability suggest it to be an important BCT for alcohol reduction apps to include. The interaction between enhanced Self-monitoring and Feedback and enhanced Action Planning on reduced AUDIT score provides further evidence for including more Control Theory congruent BCTs in behaviour change interventions. *Drink Less* should continue to be developed iteratively, with changes that result in an improved app retained and reports of changes published. Such an approach is expected to result in an effective alcohol reduction app and greater understanding of the mechanisms of action that made it so.

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8 Appendices

8.1 Instructions for coding clinical guidance and self-help documents for the inclusion of Behaviour Change Techniques (BCTs)

Reproduced with permission from supplementary files in Michie et al. (2012) [281]

1. Read through all the BCT labels and definitions and familiarise yourself with each one. Do this several times until you feel comfortable with the whole range of techniques.
2. Read through the document in full
3. Now go back and read through the BCT labels and their definitions once again
4. Then go through the document, line by line, scanning for BCTs. If you come across a quote that may look like a technique but you are uncertain, go back to the list of BCT definitions and check.
5. When you have found a BCT note that in the appropriate column.
6. Place all examples of that BCT into the 'Extract(s)' column and note the page and paragraph number.

Notes

- A technique is only present if it is explicitly stated; do not infer the presence of a technique.
- In some instances there may be inconsistencies within a document, however do not allow this to affect your coding of the document for BCTs. Instead, focus on each technique as it appears in the document and not its relation to previous sections of the document.
- If you encounter a BCT label in the document, do not assume that it has the same meaning as the given definition. Go back and read the definition of the BCT and look to see whether it meets the definition in the document.

8.2 Taxonomy of 42 BCTs used to treat excessive alcohol use identified in 9 clinical guidance/self-help documents and 3 service manuals

Reproduced with permission from supplementary files in Michie et al. (2012) [281]

Address motivation

1. Provide information on consequences of excessive alcohol consumption and reducing excessive alcohol consumption
Give, or make more salient, information about the harm caused by excessive drinking and the benefits of reducing excessive alcohol consumption
2. Identify reasons for wanting and not wanting to reduce excessive alcohol consumption
Help the client to arrive at a clear understanding of his or her feelings about reducing excessive alcohol use, why it is important to reduce and any conflicting motivations
3. Boost motivation and self-efficacy
Give encouragement and bolster confidence in ability to reduce excessive alcohol use
4. Provide normative information about others' behaviour and experiences
Give information about how the client's experience compares with other people's experiences
5. Provide feedback on performance
Give information on progress towards reducing excessive alcohol use
6. Provide information on withdrawal symptoms
Describe to drinkers what are, and are not, alcohol withdrawal symptoms, how common they are, how long they typically last, what causes them and what can be done to alleviate them
7. Provide rewards contingent on effort or progress
Give praise or other rewards for the effort the drinker is making
8. Prompt commitment from the client there and then
Encourage the client to affirm or reaffirm a strong commitment to start, continue or restart the attempt to reduce excessive alcohol use

9. Conduct motivational interviewing

This is a specific set of techniques involving prompting the client to provide self-motivating statements and evaluations of own behaviour to minimise resistance to change (includes motivational counselling). Normally this technique will be mentioned by name. Only rate this technique if explicitly referred to by name, not if one identifies specific elements of it.

10. Provide rewards contingent on successfully reducing excessive alcohol consumption

Give praise or other rewards if the client has cut down on their drinking

11. Prompt use of imagery

Teach the person to imagine successfully performing the behaviour or to imagine finding it easy to perform the behaviour, including component or easy versions of the behaviour.

12. Model/ demonstrate the behaviour

Involves *showing* the person how to correctly perform a behaviour e.g., through physical or visual demonstrations of behavioural performance, in person or remotely

13. Explain the importance of abrupt cessation

Explain why it is better to stop abruptly rather than cut down gradually if at all possible

Address self-regulation

14. Facilitate goal setting

Help the client to set goals that support the aim of reducing their drinking

15. Facilitate action planning/help identify relapse triggers

Help the client identify specific triggers that generate urge/want/need to drink and develop and reinforce plans for avoiding these or coping with the motivation to drink when it occurs

16. Advise on avoidance of social cues for drinking

Give specific advice on how to avoid being exposed to social cues for drinking (e.g. explaining to friends that you have stopped)

17. Behaviour substitution

Substituting the undesired behaviour or its associated activities with a behaviour that does not promote excessive alcohol use e.g. substituting going to the pub with going to the cinema

18. Prompt review of goals

Review how far the client has achieved the main goal of reducing excessive consumption/abstinence and any other goals that are supportive of it (e.g. putting in place plans to avoid triggers)

19. Facilitate relapse prevention and coping

Help the client understand how lapses occur and how they lead to relapse and to develop general strategies for preventing lapses or avoiding lapses turning into relapse

20. Prompt self-recording

Establish a routine of recording potentially useful information (e.g. situations or times when urges to drink are strong and less strong)

21. Facilitate barrier identification and problem solving

Help the client to identify general barriers (e.g. susceptibility to stress) that might make it harder to reduce excessive consumption/abstain and develop ways of addressing these

22. Advise on environmental restructuring

Advise on ways of changing the physical environment to minimise exposure to drinking cues (e.g. removing bottles from the house)

23. Set graded tasks

Set small achievable goals where appropriate (e.g. take one day at time)

24. Advise on conserving mental resources

Advise on ways of minimising stress and other demands on mental resources (activities that require mental effort)

25. Change routine

Advise on ways of changing daily or weekly routines to minimise exposure to drinking cues

Promote adjuvant activities

26. Advise on/facilitate use of social support

Advise on or facilitate development of social support from friends, relatives, colleagues or 'buddies'

27. Give options for additional and later support
Give information about options for additional and later support where these are available (e.g. websites, self-help groups, telephone helpline)

Address general aspects of the interaction

28. Emphasise choice
Emphasise client choice within the bounds of evidence based practice
29. Assess current readiness and ability to reduce excessive alcohol consumption
Assess current level of motivation to reduce excessive alcohol use and confidence in success
30. Offer/direct towards appropriate written materials
Distinguish what are and are not, appropriate written materials and offer/direct clients to these in ways that promotes their effective use
31. Assess current and past drinking behaviour
Assess amount drunk, age when started, pattern of drinking behaviour
32. Assess past history of attempts to reduce excessive alcohol consumption
Assess number and duration of past attempts and experiences related to these, including factors that led to drinking
33. Assess withdrawal symptoms
Assess the presence and severity of alcohol withdrawal signs and symptoms
34. Explain expectations regarding treatment programme
Explain to the client the treatment programme, what it involves, the active ingredients and what it requires of the drinker
35. Tailor interactions appropriately
Use relevant information from the client to tailor the behavioural support provided
36. Build general rapport
Establish a positive, friendly but professional relationship with the client and foster a sense that the client's experiences are understood
37. Use reflective listening
Adopt a style of interaction that involves listening carefully to the client and where appropriate reflecting back to the client key elements of what s/he is saying

38. Provide reassurance

Give general reassurance to the client that his/her experiences are normal and time limited, and provide positive expectations of success based on experience with other drinkers in the same situation.

39. Summarise information/confirm client decisions

Provide a summary of information exchanged and establish a clear confirmation of decisions made and commitments entered into

40. Elicit and answer questions

Prompt questions from the client and answer clearly and accurately

41. Elicit client views

Prompt the client to give views on drinking, reducing excessive alcohol use/abstaining and any aspect of the behavioural support programme

42. General communication skills training

This includes any technique directed at general communication skills but not directed towards a particular behaviour change. Often this may include role play and group work focusing on listening skills or assertive skills

8.3 Coded apps - Android

Title - Author	E	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	31	32	33	37	42
AlcoDroid Alcohol Tracker - Myrecek	0	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcohol Addiction Meter - Balint Farage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcohol Calorie Counter - Clickabus	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcohol Log - zero dimensional	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcohol No More - FREE - jbmApps	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Alcohol Reduction Diet - Bomberhead_lab	0	1	0	1	1	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcohol tracker - Mindstorm Software	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Alcohol Unit Wheel - Bonaventura Novellino	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcoholism Sober - Sobertool	0	1	1	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	1	1	0	0	1	0	0	0	0	1	1	0
Bierdeckel (Drink Counter) - Christian Grach	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Booze Brother Alcohol Diary - JonnyL	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drink Agent - Igor Vasicek Development	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

E = Mention of evidence. Number relates to BCT in alcohol taxonomy [281]. 1 = BCT present beyond all reasonable doubt and with clear evidence. 0 = No or unclear evidence of BCT. BCTs not used in any app are not displayed for reasons of space.

8.3 Coded apps - Android

Title - Author	E	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	31	32	33	37	42
Drink Counter - YetiStar Apps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drink Counter Widget - Innodroid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drink Meter - d Art Team	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drink Thin - 2099, LLC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DrinkControl: alcohol tracker - Happy Moments	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Drinking diary - Drive production	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drinking History - oxdb.net	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drinking mirror - Rancon	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Drinks Meter - drugs meter	1	1	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0
Know Your Limit: Alcohol Units - Michael Byers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Liquid History - Mavenjones	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Quit Alcohol - EntMedia	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

E = Mention of evidence. Number relates to BCT in alcohol taxonomy [281]. 1 = BCT present beyond all reasonable doubt and with clear evidence. 0 = No or unclear evidence of BCT. BCTs not used in any app are not displayed for reasons of space.

8.3 Coded apps - Android

Title - Author	E	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	31	32	33	37	42
Quit Drinking! - Echo Review	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Stop drinking alcohol - Oristats	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T1D Friend: Alcohol - APAApps	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Taking Control of Alcohol - Vertex Mind LLC	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcohol Postcard – CD - imensional Ltd	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Young Women and Alcohol - Dimension Ltd	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Overcoming alcoholism - KoolAppz	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
APPstinent - Heidi Steinhauser	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
The Alcohol Abuse Predictor - The Doctor Says Inc	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	1
Treating Alcohol Addiction - TrueStar Publishing	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0

E = Mention of evidence. Number relates to BCT in alcohol taxonomy [281]. 1 = BCT present beyond all reasonable doubt and with clear evidence. 0 = No or unclear evidence of BCT. BCTs not used in any app are not displayed for reasons of space.

8.4 Coded apps – iOS

Title - Author	E	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	31	32	33	37	42
Alcohol and your brain - 3Dme Pty. Ltd	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcohol Monitor - Palmanac Ltd	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Beerlog - Nicolas Lim Yew Seng	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beers by Alcohol - Canny Technologies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Change4Life drinks tracker - NHS Choices	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1	1	0	0	0	0	0	1	0	0	0
Drink Face Meter - Paul Abraham Jaimovich	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Drink Logger - Paul Collister	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Drink or Drunk - Charles Marshall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Drinkaware - Drinkaware	1	1	1	1	0	1	1	1	0	0	1	0	0	1	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0
Fewer Units - Maxamundo	0	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	0	1	0	0	0	1	1	0	0	0	0	1	0	0	0
Focus on Alcohol - John-Paul Thain	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0
iDrinkulator full - Comtek	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0
iDrinkulator Lite - Comtek	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0

E = Mention of evidence. Number relates to BCT in alcohol taxonomy [281]. 1 = BCT present beyond all reasonable doubt and with clear evidence. 0 = No evidence of BCT. BCTs not used in any app are not displayed for reasons of space.

8.4 Coded Apps - iOS

Title – Author	E	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22	23	24	25	26	31	32	33	37	42
iDrunk Free - Dirty Window Productions	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Liquor Diary - Naoya Araki	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
myDrinks- Drink Counter FREE - EachAmagination	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NHS Drinks Tracker - NHS Choices	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1
No Drink - TopOfStack Software	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NoGo - Joseph Graffi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Self Help - Northumberland, Tyne and Wear, NHS foundation Trust	0	1	0	0	0	1	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0	1	1	0	1	1	0	1
Sober Day - 10:A Media	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sober House - Bamboo Group	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stop! - John Griffiths	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alcohol Units Calculator - Essence Computing	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drunk? Pro - Jonas Kamber	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tipple - Alcohol Tracker - Sugendran Ganess	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DrinkControl (paid) - Happy Moments	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0

E = Mention of evidence. Number relates to BCT in alcohol taxonomy [281]. 1 = BCT present beyond all reasonable doubt and with clear evidence. 0 = No evidence of BCT. BCTs not used in any app are not displayed for reasons of space.

8.5 Coding approach for the BCTs in DBCIs meta-analysis

Summary

The reference point is the taxonomy of BCTs found in alcohol interventions [281]

- 1) Studies meeting the inclusion criteria will be coded for the BCTs employed;
- 2) Two reviewers code a small number of studies independently;
- 3) Findings are compared, differences resolved and the process repeated until the inter-rater reliability reaches an 80% threshold point;
- 4) Papers coded separately after this point, with occasional spot-checks for inter-rater reliability.

Detailed coding procedure

Each paper will be read line-by-line scanning for BCTs;

- 1) When a BCT has been identified:
 - a) A tick next to it will be placed in the relevant place on a worksheet containing all the BCTs identified in the taxonomy, as well other information that identifies the paper;
 - b) The text describing it will be copied into the Extracts field of the same worksheet;
 - c) The paper itself will be marked with the BCT number and where it came from.
- 2) If an extract meets the definition of a BCT but is not included in the taxonomy, then the 93-item taxonomy (V1) will be reviewed. If the BCT is found within the 93-item taxonomy a note will be made for possible inclusion in the alcohol-specific one. If the BCT is not contained within the 93-item taxonomy the inclusion of an additional BCT will be considered;
- 3) After five studies have been coded independently inter-rater reliability for identifying the same BCTs from the same text in each paper will be compared. Discrepancies will be identified and possible solutions outlined. Following this a second batch of papers will be coded and the inter-rater reliability will be rechecked. This process will continue until a minimum threshold point of 80% reliability will be obtained (which meets Landis and Koch's definition of outstanding reliability [299]);
- 4) Once this point is reached the remaining papers will be divided amongst the reviewers and coded separately, with 15% of papers checked for inter-rater reliability thereafter.

8.6 Coding guidelines for the BCTs in DBCIs meta-analysis

- DO NOT code a BCT unless the text explicitly links it to both the named target behaviour(s) and the named population(s).
- It is essential to base the BCT identification precisely on the definition given in the taxonomy.
- Presence of an action verb in an intervention description can be a good initial indicator that a BCT is being delivered.
- Do not infer the presence of a BCT. If you are unsure, do not code the BCT as present.
- Mode of delivery (tailoring/tunnelling) is not a BCT.
- Code all arms of the study, including the control but note separately. Do not code screening questions. A BCT is only present for the analyses if it is present in the intervention but not the control.
- Difference between Goal setting behaviour and outcome: Outcome is a weight loss goal as an outcome of drinking less. Behaviour is a goal to drink less.
- Self-monitoring of outcomes is recording daily weight to increase desired drinking behaviours. Self-monitoring of behaviour is recording drinking.
- Feedback on behaviour is how many drinks drunk. Feedback on outcomes is how much weight lost as a result of drinking less (or risk status for negative consequences associated with drinking).
- Behaviour is something that's being done, outcome is the result of something that was done. When in doubt, code the outcome.
- If there is feedback on any consumption measure (e.g. AUDIT) code as 2.7, as no form/frequency/duration/intensity is provided - the feedback is about risk status. This can be in addition to 2.2
- Code 2.7 as well as 6.2 if normative feedback provided, unless the NF is very specific about form, frequency, duration, intensity (in which case code 2.2 and 6.2)
- Interventions are often unclear about whether the BCT is specifically aimed at the target behaviour, if that's the case, then do not code. However, it is important to fully understand how the intervention was performed in order to code properly, as individual elements of text may not individually indicate a BCT was present, but later text may make this clearer.
- An incentive is a reward the participants are told will be given to them. Rather than a reward the intervention specifies has been given to them.
- Phrases such as: Set or agree; Analyse; Advise; Prompt; Provide; Review; Draw attention to; Establish etc. are actions taken by the experimenter/software and not the participant.

- Social BCTs may be appropriate when the extract does not match a more specific BCT e.g. “the impact of depression” is social/environmental consequences, not emotional consequences.
- The mere presence of a credible source is not enough, their views towards the target behaviour must be indicated. However, advice about drinking according to the guidelines of national limits is a credible source – provided it’s is made explicit the advice came from national guidelines. It could be goal setting too.
- There is a difference between reflective BCTs (monitoring of emotional consequences) and active ones.
- Examples of when practical social support given: A group setting in which participants discuss how to stay motivated, how to set goals – all indicate practical support was given.

Alcohol-specific guidelines

- If an email prompt is to remind people to take part, no BCT. If it’s to remind people to monitor/drink less, then Prompts and Cues.
- Information on the need to change drinking patterns code as social and environmental consequences.
- If they are informed of how their drinking relates to BAC code as Biofeedback.
- Information detailing what appropriate drinking behaviours are is not a BCT as it’s just information. If the information gives details about consequences, code accordingly.
- Reporting drinking consumption in any way is self-monitoring as they must have recorded it or monitored it in some way.
- A virtual bar (e.g. Alcohol 101) where participants can observe the effects of gender, weight, drink type and speed of consumption on BAC not a BCT.
- Being asked to indicate whether they consume too much alcohol and whether they intend to change their drinking behaviour – not enough to code a BCT.
- Indicating whether they think they drink too much and/or plan to reduce consumption, not a BCT.
- Self-efficacy could be coded as “15.3 Focus on past successes”, provided the intervention asks participants to do so, specifically to increase self-efficacy.
- A BCT was not necessarily coded just because an intervention mentioned a BCT (e.g. action planning). It needed to fit the description to be coded.

Key terms

Key terms such as: relapse prevention, skills training, stress management, motivational interviewing (and others) are coded with the specific BCTs below.

- 'Extinction' - code as the BCT 'Remove reward'
- 'Relapse prevention' - code as the BCT 'Problem solving'
- 'Coping planning' - code as the BCT 'Problem solving'
- 'Implementation intentions' - code as the BCT 'Action planning'
- 'Cognitive restructuring' - code as the BCT 'Framing / reframing'
- 'Modelling' - code as the BCT 'Demonstration of the behaviour'
- 'Positive reinforcement' - code as the BCT/s 'Material reward (behaviour)' and/or 'Material reward (outcome)' and/or 'Social reward' and/or 'Non-specific reward'
- 'Skills training' - code as the BCT 'Instruction on how to perform the behaviour'
- 'Stress management' - code as the BCT 'Reduce negative emotions'
- 'Decisional balance' - code as the BCT 'Pros and cons'
- Less well-defined packages (e.g. behavioural counselling, CBT) coded as social support (unspecified).

Notes

- All English-language supplementary materials or appendices originally included with the paper were coded. All authors were contacted for additional supplementary materials not included in the paper, any supplied were coded too.

8.7 BCTs in DBCIs – Main outcome measures

Author & year	I-M	I-SD	I-N	C-M	C-SD	C-N	Diff
Bendtsen 2015	113.4	81.1	402	120.8	86.4	529	-7.4
Bertholet 2015	84.4	83.1	367	91.5	88	370	-7.1
Blankers 2011	270	248	68	355	236	69	-85
Brendryen 2013	184.8	163.2	125	214.8	188.4	119	-30
Brief 2013	182	145.3	404	266	186.8	196	-84
Butler 2009	170.1	66.7	30	241.2	66.4	26	-71.1
Chiauzzi 2005	173.6	194	105	191.8	191	110	-18.2
Collins 2014 (DBF)	98.3	97.8	181	92.9	81.2	87	5.4
Collins 2014 (PNF)	108.6	104.7	183	92.9	81.2	86	15.7
Cunningham 2009a	151	121	92	156.4	140.1	93	-5.4
Delrahim-Howlett 2011	37.6	38.6	68	48.7	59.2	67	-11.1
Doumas 2010	120.7	127.7	13	49	61	18	71.7
Doumas 2011a	79.8	79.8	11	51.8	61.6	7	28
Ekman 2011	100.1	76	80	108.6	76	78	-8.5
Gajecski 2014	99.8	77.4	153	103.4	75.4	489	-3.6
Geisner 2015	198.2	152.6	76	200.9	141.3	81	-2.7
Hansen 2012	-14.4	272.7	450	0	0.0001	454	-14.4
Hester 1997	204.1	137.5	20	507.3	356.4	20	-303.2
Hester 2005	280.6	294	35	427.6	270.2	26	-147
Hester 2012 (exp 1)	136.1	125.7	59	192.4	174.6	71	-56.3
Hester 2012 (exp 2)	195.2	323.9	42	341.6	446.7	39	-146.4
Khadjesari 2014	162	120.8	659	152.5	114.9	671	9.5
Kypri 2009	115	96.4	1251	130	103.8	1184	-15
Kypri 2013	70	74.1	733	80	74.1	682	-10
Kypri 2014	60	59.3	1437	70	59.3	1413	-10
LaBrie 2013	119	121.8	144	126	117.6	143	-7
Lewis 2007a	117.8	63.1	65	168.6	59.9	57	-50.8
Lewis 2007b	111.6	93	64	154.3	94	78	-42.7
Lewis 2014	110.7	119.3	119	130.3	117.7	121	-19.6
Murphy 2010 (study 2)	167	158.6	38	209.9	158.8	39	-42.9
Neighbors 2006	122.2	101.8	108	161.8	149.5	106	-39.6
Neumann 2006	150.5	129.7	308	196	145.3	352	-45.5
Postel 2010	-288	213	78	-31	212	78	-257
Riper 2008	287	252	130	406	252	131	-119
Schulz 2014	-39	99.6	113	-4	195.4	84	-35
Sugarman 2009	146.44	129.08	105	137.76	127.54	110	8.68
Voogt 2013a	122	151	318	117	140	291	5
Voogt 2013b	215	206	456	224	205	451	-9
Wagener 2012	302.4	249.2	37	331.8	232.4	37	-29.4
Wallace 2011	176	160	406	188	168	448	-12
Walters 2009	169	172.3	54	180.9	198.2	61	-11.9
Weaver 2014	252	137.7	43	302.5	137.3	39	-50.5

I-M = intervention mean reduction in alcohol consumption between baseline and follow-up. I-SD, intervention standard deviation, I-N, intervention number of participants. C-M = control mean reduction in alcohol consumption between baseline and follow-up. C-SD, control standard deviation, C-N, control number of participants. Diff = difference between experimental and control mean alcohol consumption at follow-up

8.8 BCTs in DBCIs – Coded interventions

Author & year	1.1	1.2	1.3	1.4	1.6	2.2	2.3	2.4	2.6	2.7	3.1	3.2	4.1	4.2	5.1	5.2	5.3	6.2	8.2	9.1	9.2	12.2	15.4
Bendtsen 2015	1	0	0	0	0	1	1	0	1	0	1	0	1	0	1	0	1	1	0	0	1	1	0
Bertholet 2015	0	0	0	0	0	1	0	0	1	1	0	0	0	0	1	1	1	1	0	0	0	0	0
Blankers 2011	1	1	0	0	1	1	1	1	0	0	1	1	1	1	0	0	0	0	0	0	1	0	0
Brendryen 2013	1	1	0	1	1	1	1	0	0	1	1	1	1	0	0	0	1	1	0	0	0	0	1
Brief 2013	1	1	0	1	1	1	1	1	0	1	1	0	1	1	0	0	1	1	0	0	1	0	0
Butler 2009	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	1	1	1	0	1	0	0	0
Chiauzzi 2005	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	1	1	0	0	0	0	0
Collins 2014 (DBF)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Collins 2014 (PNF)	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	0	0
Cunningham 2009a	0	0	0	0	0	1	0	0	1	1	0	0	1	0	1	1	1	1	0	1	0	0	0
Delrahim-Howlett 2011	0	0	0	0	0	1	1	0	0	1	1	0	1	0	1	1	1	1	0	1	0	0	0
Doumas 2010	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0
Doumas 2011a	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	1	1	0	0	0	0	0
Ekman 2011	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gajecki 2014	0	0	0	1	1	1	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Geisner 2015	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	0
Hansen 2012	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0	0
Hester 1997	1	1	0	0	1	1	1	0	1	0	1	0	1	1	0	0	0	1	0	1	0	0	0
Hester 2005	1	1	0	1	0	1	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	0
Hester 2012 (exp 1)	1	1	0	1	0	1	0	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0
Hester 2012 (exp 2)	1	1	0	1	0	1	0	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	0

Number relates to BCT in 93-item taxonomy [8]. 1 = BCT present beyond all reasonable doubt and with clear evidence. 0 = No or unclear evidence of BCT. BCTs used in less than four DBCIs not displayed for reasons of space.

8.8 BCTs in DBCIs – Coded interventions

Author & year	1.1	1.2	1.3	1.4	1.6	2.2	2.3	2.4	2.6	2.7	3.1	3.2	4.1	4.2	5.1	5.2	5.3	6.2	8.2	9.1	9.2	12.2	15.4
Khadjesari 2014	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0
Kypri 2009	0	0	0	0	0	1	0	0	1	1	1	0	1	0	1	1	1	1	0	0	0	0	0
Kypri 2013	0	0	0	0	0	1	0	0	1	1	1	0	1	0	1	1	1	1	0	0	0	0	0
Kypri 2014	0	0	0	0	0	1	0	0	1	0	1	0	1	0	1	1	1	1	0	0	0	0	0
LaBrie 2013	0	0	1	0	0	1	0	0	1	1	0	0	1	0	0	1	1	1	0	0	1	0	0
Lewis 2007a	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lewis 2007b	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Lewis 2014	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Murphy 2010 (study 2)	0	0	1	0	0	1	0	0	1	1	1	0	1	0	0	1	1	1	0	1	1	0	0
Neighbors 2006	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Neumann 2006	0	1	1	1	0	1	0	0	0	1	1	1	1	0	1	0	1	0	0	1	1	0	0
Postel 2010	1	1	0	1	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	1	1	0	1
Riper 2008	0	1	1	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Schulz 2014	0	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	1	1	0	1	1	0	0
Sugarman 2009	0	0	0	0	0	1	0	0	1	1	0	0	1	0	1	0	1	1	0	0	0	0	0
Voogt 2013a	1	1	0	1	0	1	0	0	0	1	1	0	1	0	0	1	1	1	0	0	0	0	0
Voogt 2013b	1	1	0	1	0	1	0	0	0	1	1	0	1	0	1	1	1	1	0	0	0	0	0
Wagener 2012	1	0	0	1	0	1	0	0	1	1	0	0	0	1	1	1	1	1	0	0	1	0	0
Wallace 2011	0	1	1	1	0	0	1	1	1	1	0	1	1	1	0	1	1	1	0	0	1	0	1
Walters 2009	0	0	0	1	0	1	1	1	1	1	1	0	0	0	0	1	1	1	0	1	1	0	1
Weaver 2014	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	1	1	0	0	0	0	0

Number relates to BCT in 93-item taxonomy [8]. 1 = BCT present beyond all reasonable doubt and with clear evidence. 0 = No or unclear evidence of BCT. BCTs used in less than four DBCIs not displayed for reasons of space.

8.9 Usability study interview topics

Study 1 – ‘Think aloud’

Tasks

1. Register for the app and complete baseline measures
2. Add drinks to the drinking diary
3. Set a goal
4. Create an action plan
5. Play the thanks/no thanks game
6. Try the identity module
7. Browse the app

Questions

1. What are your overall views toward the app?
2. Was there anything you particularly disliked?
3. Was there anything you found particularly hard to use?
4. Was there anything you particularly liked?
5. Was there anything you found particularly easy to use?
6. Anything you wanted to see there/expected to see there but didn't?
7. Do you have any suggestions for how the app could be improved?
8. Are there any other comments you would like to make?

Study 2 – Semi-structured interview

Questions

1. What made you choose this app in preference to others?
2. What was the registration process like? Was it too long? Too intrusive?
3. What did you think of the feedback about your drinking? Did you believe it? What was your response to it?
4. What were your first impressions of the app?
5. What was your first impression of the dashboard?
6. What are your views of it now?
7. Do you remember what you did first when using the app and your views toward it?
8. Did you set any goals? How did you find the process?
9. Have you received any feedback yet? What do you think of it?
10. What do you think of the Mood Diary?
11. Did you set any action plans? How did you find the process? Have you found them useful?
12. How have you found the process of adding drinks?
13. Have you played the game? How did you find it? Were the instructions clear?
14. Have you tried the Identity section? How did you find it?
15. What do you think of the help section?
16. What are your overall views toward the app?
17. Was there anything you particularly disliked?
18. Was there anything you found particularly hard to use?
19. Was there anything you particularly liked?
20. Was there anything you found particularly easy to use?
21. Anything you wanted or expected to see but didn't?
22. Do you have any other suggestions for how the app could be improved?
23. Are there any other comments you would like to make?

8.10 Changes made to the app in response to the usability study – organised according to theme

Main theme	Sub-theme	Changes made
'Feeling lost and unsure of what to do next'	'Help me when first using the app'	Stepped guide added. This signified to participants that the registration process had finished and helped them with their first use of the app. The three tasks participants were asked to complete were: 1) set a goal, 2) enter some drinks and, 3) explore the app. Having done this, participants were expected to be reasonably familiar with the app.
	'How do I get to where I need to be?'	The navigation of the app was made consistent throughout. Some screens had hidden the navigation bar at the bottom of the screen, these were adjusted so that the navigation bar was visible again. 'Back' links were added so users could retrace their steps. A bug in navigation was fixed.
'Make the app easy to use'	'Do not make me work'	All functions on the app were reviewed to determine how user burden could be further reduced. For example, in addition to logging their drinks each day, participants were originally encouraged to use a different module of the app each day. This was changed so that encouragement to use other modules was only made visible every three days. The title of this area was renamed from "Things to do today" to "We suggest" to further reduce participants' perceived burden. Error messages on forms indicated which field needed completing. Elements that users might expect from their use of other apps (e.g. a calendar when a date is tapped) were added.
	'Provide clear guidance throughout'	Information buttons (i) were added to all relevant screens of the app. Text on these screens helped participants understand the purpose of the screen, how it should be used and what type of input was required. To alert users to the presence of the (i) button, a notification was subtly displayed to users at the top of the 1 st , 3 rd , 10 th and 20 th screen they visited.
	'Make it visually appealing'	The Dashboard and Progress screens were made more graphical with the addition of icons and the reduction of text. Other text heavy screens were edited down. Feedback about calorie input from alcohol and money spent on alcohol was displayed in figures rather than graphs. The visual design of feedback about goals was improved. The design of other screens deemed important for engagement (such as "Add Drinks") was reviewed and improved where possible.
	'Do not overwhelm me'	Improving the visual design of the app was considered the main change to reduce feelings of being overwhelmed in participants. Some participants expressed the feeling at the number of modules the app contained, this could not be addressed because of the study design.
	'Blame myself, not the app, if it's too hard to use'	The app was made easier to use, as described above.

Main theme	Sub-theme	Changes made
'Make the app beneficial and rewarding to use'	'How will it help me/continue to help me?'	Greater information was added about how each module might help a participant drink less alcohol. More alcohol-specific Implementation Intentions were provided as examples.
	'Reward me for my achievements'	More positive reinforcement for effort or progress was provided. A sound was played and on-screen message of congratulations were displayed when participants recorded a drink, set a goal or created an action plan. A new area on the dashboard was created: 'Your achievements'. This rewarded streaks of continuous diary entries and provided feedback against goals for the last completed week.
	'Do not be judgemental'	The daily prompt to complete a drinking diary was edited to remove any reference to alcohol (was "Please complete your drinking diary", became "Please complete your diary"). All screens on the app were reviewed for possible judgemental language.
	'Be friendly and funny'	Text throughout the app was reviewed and, where possible, made more informal and humorous.
	'Tell me I can trust the app'	Participants who expressed doubts toward the app usually did so because they didn't believe the feedback about how their drinking compared to other people of their gender and age group in the UK (evaluated in separate thesis [18]). To promote trust, more information was given about why the comparison data were reliable. Other screens were added to prepare users for information they might find shocking.
	'Update me on how I am doing'	The signposting of feedback was improved by providing clearer links on the Dashboard. Feedback was improved by adding colour gradients on the calendar to differentiate between a no drinking day, a light drinking day and a heavy drinking day and changing the Mood Diary comparisons so that days when no or less than six units of alcohol were consumed were compared with days when more than six units of alcohol were consumed.

8.11 Details of intervention modules evaluated in this thesis

Module	Objective	Details of module		
		Enhanced	Minimal	BCTs in 'enhanced' version
Self-monitoring and Feedback	Facilitate easy and on-going recording of alcohol consumption; provide feedback on consumption, consequences of consumption and progress against goals.	Ability to record drinks. Graphs showing units consumed, calories consumed, amount spent on alcohol. Record mood, productivity, clarity, sleep quality and provide feedback about how they differ on mornings after heavy drinking compared to mornings after light/no drinking. Feedback on progress towards goals: as the week progresses, on the past complete week and on all previous weeks.	Ability to record drinks. No feedback provided or other self-monitoring facilitated.	'Self-monitoring of behaviour', 'Self-monitoring of outcomes of behaviour', 'Feedback on behaviour', 'Feedback on outcomes of behaviour', 'Salience of consequences', 'Information about emotional consequences', 'Review behaviour goals', 'Discrepancy between current behaviour and goal', 'Social reward', 'Self-reward' and 'Non-specific reward'
Action Planning	Allow users to create implementation intentions for dealing with difficult drinking situations.	Create implementation intentions, review implementation intentions already created, gain understanding of why to set implementation intentions.	Gain understanding of why to set implementation intentions only.	'Action planning', 'Credible source'

8.12 Details of intervention modules evaluated in separate thesis

Module	Objective	Details of module		
		Enhanced	Minimal	BCTs in 'enhanced' version
Normative Feedback	Inform users of the social drinking norm and alert them to any discrepancy between how they believe their drinking compares to how it actually compares with normal.	Questions assessing how users think they compare with others. Infographics illustrating how user's drinking actually compares with other adults and others of same gender and age.	Text on risks of drinking too much (from PHE website).	'Social comparison'
Identity Change	Help users foster a change in their identity so that they do not see themselves, or wish to see themselves, as "drinkers".	Memos – record messages about drinking or when drunk to watch in the future. "I am": identifying and considering values that are important to a user, and whether they do not live up to those values when they have drunk too much. Flipsides of drinking: Providing examples of the negative sides of positive alcohol expectancies.	Text on how identity is an important factor in how we behave and advise to think about the undesired consequences of drinking too much.	'Identification of self as role model', 'Incompatible beliefs', 'Valued self-identity', 'Identity associated with changed behaviour', 'Information about health/social/emotional consequences', 'Salience of consequences', 'Anticipated regret', 'Pros and cons', 'Framing/reframing'
Cognitive Bias Re-training	Use a form of cognitive bias modification to strengthen cognitive control over the automatic biases to approach alcohol that predict alcohol use that exist amongst the users through an engaging game.	Game with all alcohol related pictures associated with "avoid" and all soft drink pictures associated with "approach". Additional text on why and how this sort of game is believed to work.	Game with 50% of alcohol related pictures associated with "avoid" and 50% associated with "approach". Same for soft drink pictures.	

These modules are evaluated in Garnett C. Development and evaluation of a theory- and evidence-based smartphone app to help reduce excessive alcohol consumption. University College London; 2017.

8.13 Experimental group matrix

Group	Self-monitoring and Feedback	Action Planning	Normative Feedback	Identity Change	Cognitive Bias Re-training
1	Enhanced	Enhanced	Enhanced	Enhanced	Enhanced
2	Enhanced	Minimal	Enhanced	Enhanced	Enhanced
3	Minimal	Enhanced	Enhanced	Enhanced	Enhanced
4	Minimal	Minimal	Enhanced	Enhanced	Enhanced
5	Enhanced	Enhanced	Enhanced	Enhanced	Minimal
6	Enhanced	Minimal	Enhanced	Enhanced	Minimal
7	Minimal	Enhanced	Enhanced	Enhanced	Minimal
8	Minimal	Minimal	Enhanced	Enhanced	Minimal
9	Enhanced	Enhanced	Enhanced	Minimal	Enhanced
10	Enhanced	Minimal	Enhanced	Minimal	Enhanced
11	Minimal	Enhanced	Enhanced	Minimal	Enhanced
12	Minimal	Minimal	Enhanced	Minimal	Enhanced
13	Enhanced	Enhanced	Enhanced	Minimal	Minimal
14	Enhanced	Minimal	Enhanced	Minimal	Minimal
15	Minimal	Enhanced	Enhanced	Minimal	Minimal
16	Minimal	Minimal	Enhanced	Minimal	Minimal
17	Enhanced	Enhanced	Minimal	Enhanced	Enhanced
18	Enhanced	Minimal	Minimal	Enhanced	Enhanced
19	Minimal	Enhanced	Minimal	Enhanced	Enhanced
20	Minimal	Minimal	Minimal	Enhanced	Enhanced
21	Enhanced	Enhanced	Minimal	Enhanced	Minimal
22	Enhanced	Minimal	Minimal	Enhanced	Minimal
23	Minimal	Enhanced	Minimal	Enhanced	Minimal
24	Minimal	Minimal	Minimal	Enhanced	Minimal
25	Enhanced	Enhanced	Minimal	Minimal	Enhanced
26	Enhanced	Minimal	Minimal	Minimal	Enhanced
27	Minimal	Enhanced	Minimal	Minimal	Enhanced
28	Minimal	Minimal	Minimal	Minimal	Enhanced
29	Enhanced	Enhanced	Minimal	Minimal	Minimal
30	Enhanced	Minimal	Minimal	Minimal	Minimal
31	Minimal	Enhanced	Minimal	Minimal	Minimal
32	Minimal	Minimal	Minimal	Minimal	Minimal

8.14 Full results of factorial ANOVA on past week consumption

	F	P
Normative Feedback (NF)	0.30	0.59
Cognitive Bias Re-training (CBR)	0.39	0.53
Identity Change (IC)	2.16	0.14
Self-monitoring and Feedback (SM)	0.78	0.38
Action Planning (AP)	0.14	0.71
NF x CBR	4.68	0.03
NF x IC	0.81	0.37
NF x SM	2.20	0.14
NF x AP	0.08	0.78
CBR x IC	0.94	0.33
CBR x SM	2.80	0.10
CBR x AP	0.01	0.93
IC x SM	0.39	0.54
IC x AP	0.04	0.84
SM x AP	0.22	0.64
NF x CBR x IC	1.86	0.17
NF x CBR x SM	0.03	0.87
NF x CBR x AP	4.94	0.03
NF x IC x SM	0.03	0.87
NF x IC x AP	0.29	0.59
NF x SM x AP	0.14	0.71
CBR x IC x SM	0.00	0.96
CBR x IC x AP	0.28	0.60
CBR x SM x AP	2.68	0.10
IC x SM x AP	0.52	0.47
NF x CBR x IC x SM	1.08	0.30
NF x CBR x IC x AP	0.01	0.93
NF x CBR x SM x AP	0.49	0.48
NF x IC x SM x AP	0.05	0.82
CBR x IC x SM x AP	0.85	0.36
NF x CBR x IC x SM x AP	0.12	0.73

8.15 Full results of factorial ANOVA on change in AUDIT score

	AUDIT score	
	F	P
Normative Feedback (NF)	1.60	0.21
Cognitive Bias Re-training (CBR)	0.11	0.75
Identity Change (IC)	0.09	0.77
Self-monitoring and Feedback (SM)	0.35	0.56
Action Planning (AP)	1.75	0.19
NF x CBR	1.46	0.23
NF x IC	0.22	0.64
NF x SM	0.78	0.38
NF x AP	1.19	0.28
CBR x IC	0.28	0.60
CBR x SM	0.50	0.48
CBR x AP	1.60	0.21
IC x SM	0.46	0.50
IC x AP	2.34	0.13
SM x AP	5.82	0.02
NF x CBR x IC	0.01	0.91
NF x CBR x SM	0.03	0.86
NF x CBR x AP	0.07	0.79
NF x IC x SM	0.20	0.66
NF x IC x AP	0.03	0.86
NF x SM x AP	1.39	0.24
CBR x IC x SM	0.02	0.88
CBR x IC x AP	0.09	0.77
CBR x SM x AP	0.35	0.56
IC x SM x AP	0.54	0.46
NF x CBR x IC x SM	1.06	0.30
NF x CBR x IC x AP	1.99	0.16
NF x CBR x SM x AP	0.03	0.86
NF x IC x SM x AP	0.20	0.66
CBR x IC x SM x AP	0.54	0.46
NF x CBR x IC x SM x AP	0.31	0.58

8.16 Full results table for secondary outcome measure – app usage

	Number of sessions		Length per session	
	F	P	F	P
Normative Feedback (NF)	1.64	0.20	1.64	0.20
Cognitive Bias Re-training (CBR)	0.05	0.82	0.05	0.82
Identity Change (IC)	0.86	0.36	0.86	0.36
Self-monitoring and Feedback (SM)	12.73	<0.001	12.73	<0.001
Action Planning (AP)	0.17	0.68	0.17	0.68
NF x CBR	0.40	0.53	0.40	0.53
NF x IC	2.33	0.13	2.33	0.13
NF x SM	0.92	0.34	0.92	0.34
NF x AP	2.49	0.12	2.49	0.12
CBR x IC	0.14	0.70	0.14	0.70
CBR x SM	0.24	0.62	0.24	0.62
CBR x AP	0.26	0.61	0.26	0.61
IC x SM	0.00	0.96	0.00	0.96
IC x AP	0.19	0.66	0.19	0.66
SM x AP	0.03	0.86	0.03	0.86
NF x CBR x IC	0.86	0.36	0.86	0.36
NF x CBR x SM	<0.001	1.00	<0.001	1.00
NF x CBR x AP	0.12	0.73	0.12	0.73
NF x IC x SM	0.12	0.73	0.12	0.73
NF x IC x AP	0.28	0.60	0.28	0.60
NF x SM x AP	6.37	0.01	6.37	0.01
CBR x IC x SM	0.54	0.46	0.54	0.46
CBR x IC x AP	1.81	0.18	1.81	0.18
CBR x SM x AP	0.60	0.44	0.60	0.44
IC x SM x AP	2.93	0.09	2.93	0.09
NF x CBR x IC x SM	5.73	0.02	5.73	0.02
NF x CBR x IC x AP	1.20	0.27	1.20	0.27
NF x CBR x SM x AP	0.29	0.59	0.29	0.59
NF x IC x SM x AP	0.01	0.91	0.01	0.91
CBR x IC x SM x AP	0.48	0.49	0.48	0.49
NF x CBR x IC x SM x AP	0.24	0.63	0.24	0.63

8.17 Full results table for secondary outcome measure – usability ratings

	Helpfulness		Ease of use		Recommendation		Satisfaction	
	N=182		N=178		N=178		N=178	
	F	P	F	P	F	P	F	P
Normative Feedback (NF)	0.02	0.90	0.72	0.40	0.28	0.60	0.17	0.68
Cognitive Bias Re-training (CBR)	0.03	0.86	0.22	0.64	1.07	0.30	0.03	0.86
Self-monitoring and Feedback (SM)	4.39	0.04	1.11	0.29	5.02	0.03	6.60	0.01
Action Planning (AP)	0.01	0.93	0.47	0.49	0.33	0.57	1.30	0.26
Identity Change (IC)	0.17	0.68	0.02	0.89	0.40	0.53	0.00	0.95
NF x CBR	0.42	0.52	3.81	0.05	0.02	0.88	0.09	0.76
NF x IC	0.13	0.72	0.01	0.91	0.01	0.92	0.02	0.90
NF x SM	0.08	0.79	1.61	0.21	3.11	0.08	1.58	0.21
NF x AP	2.52	0.12	0.49	0.49	0.04	0.85	0.21	0.65
CBR x IC	0.73	0.40	<0.001	1.00	0.08	0.78	0.02	0.89
CBR x SM	0.33	0.57	0.22	0.64	0.00	0.98	0.29	0.59
CBR x AP	0.03	0.87	<0.001	0.99	0.01	0.91	0.05	0.82
IC x SM	<0.001	1.00	0.34	0.56	0.14	0.71	0.00	0.96
IC x AP	0.01	0.93	0.21	0.64	0.01	0.94	0.00	0.96
SM x AP	0.12	0.73	0.63	0.43	0.20	0.65	0.05	0.82
NF x CBR x IC	0.18	0.67	0.68	0.41	0.25	0.62	0.11	0.74
NF x CBR x SM	1.30	0.26	1.12	0.29	0.15	0.70	0.52	0.47
NF x CBR x AP	0.93	0.34	0.51	0.48	0.88	0.35	0.15	0.70
NF x IC x SM	0.66	0.42	2.64	0.11	1.39	0.24	3.10	0.08
NF x IC x AP	1.92	0.17	0.19	0.66	1.13	0.29	0.00	0.95
NF x SM x AP	1.40	0.24	1.59	0.21	<0.001	1.00	0.00	0.98
CBR x IC x SM	0.65	0.42	0.22	0.64	0.07	0.80	0.49	0.49
CBR x IC x AP	0.27	0.61	0.03	0.86	0.05	0.82	0.00	0.97
CBR x SM x AP	1.43	0.23	0.71	0.40	0.09	0.76	0.38	0.54
IC x SM x AP	8.44	0.00	2.50	0.12	3.61	0.06	10.62	0.00
NF x CBR x IC x SM	0.66	0.42	0.17	0.68	0.13	0.72	0.15	0.70
NF x CBR x IC x AP	2.32	0.13	0.43	0.52	3.37	0.07	0.48	0.49
NF x CBR x SM x AP	0.08	0.77	0.03	0.88	0.28	0.60	0.58	0.45
NF x IC x SM x AP	2.64	0.11	0.83	0.37	1.10	0.30	3.99	0.05
CBR x IC x SM x AP	0.63	0.43	0.37	0.54	1.53	0.22	0.95	0.33
NF x CBR x IC x SM x AP	0.30	0.58	0.88	0.35	2.47	0.12	1.07	0.30

8.18 Sensitivity analysis assessing main effects of intervention modules on change in past week alcohol consumption among responders-only

	Mean change in past week alcohol consumption, units per week (SD)		F	P
	Intensive	Minimal		
Normative Feedback	-14.1 (25.07)	-14.6 (23.03)	0.12	0.73
Cognitive Bias Re-training	-16.0 (23.73)	-12.7 (24.47)	0.13	0.72
Identity Change	-10.8 (23.17)	-18.2 (24.65)	4.26	0.04
Self-monitoring & Feedback	-14.8 (21.57)	-13.7 (26.92)	0.05	0.82
Action Planning	-13.9 (20.87)	-14.6 (26.92)	0.02	0.90

8.19 Sensitivity analysis – main effects of intervention modules on change in AUDIT score among responders-only

	Mean change in AUDIT score (SD)		F	P
	Intensive	Minimal		
Normative Feedback	-3.1 (4.34)	-2.7 (4.77)	0.69	0.41
Cognitive Bias Re-training	-3.2 (3.94)	-2.6 (5.01)	0.28	0.60
Identity Change	-2.6 (4.72)	-3.2 (4.31)	1.02	0.32
Self-monitoring & Feedback	-2.8 (4.41)	-3.0 (4.70)	0.04	0.84
Action Planning	-3.5 (4.51)	-2.3 (4.49)	2.67	0.11

8.20 Feedback given on AUDIT score

AUDIT Score	Feedback given
Between 0-7	<p>{Green text}</p> <p>Your results indicate you're not at risk of physical and/or psychological alcohol-related harm.</p> <p>Your score was X which lies in the range of 0-7 for this risk zone.</p>
Between 8-15	<p>(Yellow text)</p> <p>Your results indicate you're putting yourself at increasing risk of physical and/or psychological alcohol-related harm.</p> <p>Your score was X which lies in the range of 8-15 for this risk zone.</p>
Between 16-19	<p>(Orange text)</p> <p>Your results indicate you're likely to be experiencing physical and/or psychological alcohol-related harm.</p> <p>Your score was X which lies in the range of 16-19 for this risk zone.</p>
Between 20-40	<p>(Red text)</p> <p>You results indicate the possibility of alcohol dependence. You are welcome to continue to use this app though we strongly advise you to contact your GP for further support.</p> <p>Your score was X which lies in the range of 20-40 for this risk zone.</p>

8.21 User-selectable options for alcoholic drinks





Type	Options		Volume
Beer	Ale Lager Stout Craft		Very small bottle (275ml) ½ pint (284ml) Small bottle (330ml) Can (440ml) Large bottle (500ml) Large can (500ml) Pint (568ml)
Cider	(None)		Very small bottle (275ml) ½ pint (284ml) Small bottle (330ml) Can (440ml) Large bottle (500ml) Large can (500ml) Pint (568ml)
Wine	Red White Rose Sparkling		Small glass (125ml) Medium glass (175ml) ¼ bottle (187.5ml) Large glass (250ml) 1/3 bottle (250ml) ½ bottle (375ml)
Fortified wine	Sherry Port Madeira Marsala		Glass (150ml)
Spirits	Options Whisky Vodka Rum Gin	Add Nothing (neat) Coke Lemonade Lime Juice Diet coke Diet lemonade Tonic Ginger beer/ale Soda Other	Single (25ml) Double (50ml) Triple (75ml)
Alcopops	None		Small bottle (275ml) Bottle (330ml)

Items appear in the order presented in the app. Items in bold were selected by default.

8.22 Goal feedback

Criteria	Feedback
Goal exceeded by $\geq 20\%$ once:	Overachiever! Goal smashed. Well done.
Goal exceeded by $\geq 20\%$ twice in a row:	Whoa, there goes that goal again. Twice in a row too. Is this an unusual period or do you think the goal is a bit easy? <u>You can make it harder if you like.</u>
Goal hit; one of (delivered at random):	Get you! Good work on hitting your goal. Congratulations on a great [week/month] of achievement. Feel proud? You should. Goal hit. Good work. You're great. That's your goal got! I'd pat you on the back if I had arms. Well done, you hit your goal. Keep going.
Goal missed; one of (delivered at random):	Didn't quite make this one. Close though. You can do this. Just missed this goal. It's definitely within reach though. Nearly made it. Just need to do a bit more and you'll make it next time. That was close! Won't take much more to get that glorious green tick. Almost! Bit more of a push and you'll get this goal.
Goal missed by $\geq 20\%$:	You didn't hit your goal this week. No problem, keep going.
Goal missed by $\geq 20\%$ twice in a row:	Looks like you're having a bit of difficulty with this one. Is it an unusual period, or do you think the goal is a bit much of a stretch? <u>You can make it a slightly easier if you like.</u>

If goals were exceeded or missed by $\geq 20\%$ twice in a row the underlined text in the feedback provided linked to the Goal Setting screen where a goal could be amended.

Icon	Represents
	Goal exceeded by $\geq 20\%$
	Goal hit
	Goal missed
	Goal missed by $\geq 20\%$

8.23 The Help area of the app

The help area consisted of information about alcohol, app settings, and information about the app.

8.23.1 Information about alcohol

‘Information about alcohol’ contained screens explaining the UK’s recommended guidelines for alcohol consumption [32], information about the harms of drinking and the benefits of not drinking as well as information about how to set good goals and how to set action plans. These last two screens were duplicated from their existing position in the Goal Setting and Action Planning modules to make finding them easier for participants who might consider the ‘Help’ area their most natural location. A second link, entitled ‘Can’t stop drinking’ provided links to the NHS Alcohol Addiction Services and Alcoholics Anonymous, for people who may need more extensive support than the app could provide.

8.23.2 App settings

‘App Settings’ allowed participants to change the time of the reminder that prompted them to complete a log of their drinking. Participants could also turn the reminder off. Text explained that it was best to set this reminder in the morning, when memories are fresh, and at a time that would be optimum for a participant’s morning routine.

8.23.3 Information about the app

‘Information about the app’ provided links to a number of other screens. ‘Contact’ allowed participants to get in touch with the research team should they have questions or need help; ‘The team’ provided information about the expertise of the research team and ‘References’ contained citations of studies that had informed development of the app. The latter two screens were intended to establish the app as a credible source, a technique associated with

the effectiveness of DBCIs [Chapter 3], and the popularity of apps [Chapter 2]. ‘The study and you’ contained the same information as on the ‘participant information’ screen in case participants wanted to review that information. ‘Privacy policy’ contained brief information about the study’s data storage procedure and reminded participants they could withdraw from the study at any time. ‘Opt out’ allowed participants to opt-out of the study; this was made a two-step process to prevent unintentional selection. Lastly, ‘Rate this app’ took participants to the Apple App Store where they could leave a review for the app.

All copy in the help area was written concisely and supported by references where relevant. The tone of voice used was friendly and knowledgeable.

8.23.4 Behaviour change techniques

BCT	App Location	Thesis Section
3.1 Social support (unspecified)	Links for additional support/ Tips for drinking less	8.23.1
4.1 Instruction on how to perform the behaviour	Tips for drinking less	8.23.1
5.1 Information about health consequences	Harms of drinking	8.23.1
5.3 Information about social and environmental consequences	Harms of drinking	8.23.1
5.6 Information about emotional consequences	Harms of drinking	8.23.1
9.1 Credible source	About us	8.23.3
10.2 Material reward (behaviour)	Tips for drinking less	8.23.1
12.2 Restructuring the social environment	Tips for drinking less	8.23.1
12.3 Avoidance/reducing exposure to cues for the behaviour	Tips for drinking less	8.23.1

8.24 Brief given to developers

Introduction:

We wish to develop an app for iOS and Android devices which will:

- Help users reduce their consumption of alcohol
- Test which of the modules it contains are most effective in achieving this
- Create a rewarding and satisfying user experience
- Engage users over a prolonged period of time

What we ideally want from a developer/programmer:

We require a highly motivated and experienced developer/designer or development team to work with us in designing and building the app. The complexity of the project will mean that the relationship will be intensively collaborative and will involve working closely with our project manager. We will require you to respond in a timely manner to queries, design/functionality amendments and content updates from the project manager throughout the scope of the project. In addition, we will be seeking developers who can not only build the app to our specifications but who can also use their experience and expertise to advise on ways in which the aims of the project can best be achieved.

What we ideally want from the app:

An aesthetically appealing, easy to use app that creates a positive and satisfying user experience. As this is a research project it is important not just that the app is downloaded in large numbers but also that users remain engaged for a substantial period of time. In addition, we need to find ways to contact people who have stopped using the app as their responses to our follow-up questionnaires are of great importance.

Target audience

Men and women aged 18+ who want to reduce their consumption of alcohol. The app's design should appeal to as wide an audience as possible and all features should be intuitive to use. We will be capturing data from use of the app (screens visited, time on those screens etc., perhaps using Google Analytics) and explicitly from user entries as detailed on the wireframes. The challenges for users in entering data should be taken into account by the development team.

Proposed content and structure:

The app will contain the following modules, see the included Wireframes (not included in this thesis, available from the author on request) for more details about each. Please note that the fine detail of the wireframes will be confirmed before work commences.

Questionnaires

- Invitation to consent screen which users must agree to in order to access the rest of the app
- Ten question multiple-choice questionnaire (AUDIT). All items will be scored according to a supplied scale, total figure for each participant to be calculated
- Feedback supplied to each user based on the calculated score (four different blocks of feedback)
- Demographic questionnaire

Self-monitoring

- Ability for users to easily and quickly record the alcoholic drinks they've consumed
- Alcoholic drinks divided into the groups detailed in the wireframes
- Specifics of drinks to include ABV percent (in two decimal point increments), type and quantity of alcoholic beverage, date of consumption (past days allowed, no future days) and cost of drinks. Defaults for ABV and volume differ according to the type of drink chosen from point 2 (above)
- Pleasing confirmation sound played when consumption successfully recorded
- Confirmation screen detailing record entered. Ability to edit/delete entries made
- All drinks entered into list of favourites, unless already present in that list. User ability to edit and delete items. Mechanism by which users can easily add drinks in their favourites to their record of consumption
- Reminder allowing users to be prompted to enter their consumption of alcoholic drinks – either once per day and/or at specific times, both to be user set and editable.
- Drinking diary questionnaire
- Intoxication tests and graph(s) of results

Feedback

- Graphs indicating the user's consumption over time (units of alcohol consumed, scores from the drinking diary questionnaire, calories consumed, amount spent – calories and unit conversions to be supplied)
- Information about how the consumption compares to data from fitness, calorie counting or sleep tracking apps (this data captured from iOS8 Healthkit or from the app's APIs, these apps to be specified)
- Database generated information about how the user's consumption compares to their goal(s)

- Database generated information about how the user's consumption is changing over time.
- Information from points 2-4 to be presented in graphical rather than text form wherever possible
- Questionnaire about the user's motives for reducing their drinking. Answers here adjusts the order in which the graphs and information are shown (point 1)

Goal setting

- Ability for users to choose a pre-set goal or set one of their own
- Editable list of goals set
- Ability for users to set an action plan (possibly). User editable.
- List of what has and has not worked for users (taken from responses to the Self-monitoring drinking diary questionnaire)

Normative misperceptions

- 40 point slider allowing users to indicate their answer to two questions. Some content taken from answers to the demographic questionnaire (shown in green on the wireframes)
- Screens that show how the user's AUDIT score compares to other people's in the UK (comparison information to be supplied) and how the answer to the two questions in point 1 (above) compares to the normal rates of alcohol consumption in the UK (database generated information shown in green on the wireframes, comparative information to be supplied).

Cognitive Bias Re-training

- Users are randomised to either the experimental or control condition
- Each time they visit this feature they are further randomised to Portrait Away or Landscape Away
- Test run. Feedback about correct and incorrect actions given to user on screen. Repeats automatically five times. User has option to restart test run.
- Experiment. Pictures (to be supplied) will be of alcoholic and soft drinks. User responses to all pictures recorded. This to comprise: time taken from user first touching screen to removing picture from screen and picture number in question. E.g. user xyz picture 15, up, 205ms, 12th November 2014, 15:12. Repeats 40 times with a break after 20 times. Users can stop the experiment at any time with their scores to this point recorded.
- More details on randomisation: Users are randomly allocated to either an experimental or control condition. Once in this condition they will randomly be given either version Portrait Away (A) or Landscape Away (B) of the experiment each time they open this

feature. This results in four different circumstances:

- Experimental group, Landscape Away
- Alcoholic drinks shown in landscape 100% of time and soft drinks in portrait 100% of time
- Experimental group, Portrait Away
- Alcoholic drinks shown in portrait 100% of time and soft drinks in landscape 100% of time
- Control group, Landscape Away
- Alcoholic drinks shown in landscape 50% of time and soft drinks in portrait 50% of time
- Control group, Portrait Away
- Alcoholic drinks shown in portrait 50% of time and soft drinks in landscape 50% of time
- Same group of pictures will be shown in all four circumstances. Landscape and portrait pictures will be differentiated by a landscape or portrait border around the picture
- Graphs comparing how the user did on this trial with their own previous trials, and against other people in the same trial condition

Identity

- Ability to record videos with two questions asked of users before recording starts. Users can delete or view recorded videos
- Ability to set reminders to record or watch videos. User can edit or delete reminders
- User ability to take selfie
- User can pick from list of labels, attributes or rules that apply to themselves. Can also add their own
- Selected label/attribute/rules appears next to/or if easier, an overlay on top of the picture of user
- User can choose label/attribute/rules that does not apply to them after consuming alcohol
- Examples of values/attributes and how drinking can contradict them. Each one of which has descriptive text viewable on tap
- Various screens of positive aspects of drinking accompanied by their negative side

Info and settings

- Ability to adjust reminders
- Follow-up questionnaire to be triggered 1 and 3 months after the user starts using the

app

- Prompt asking users to supply their email for follow-up purposes triggered after 3 uses of the app
- Rate this app screen (triggered after 7, 14 and 21 uses of the app)

Randomisation

- Each of the above modules will have two versions: Enhanced and Minimal.
- The wireframes contains text in read indicating whether the screen or parts of the screen are for all users or for a subset of users (e.g. self-monitoring enhanced or self-monitoring minimal)
- App menus must reflect the options available for the user within that group

Technical requirements

- App that runs natively on iOS7 and Android 2.33 - and above
- Design that accommodates the various screen sizes of these devices (excluding tablets)
- Ability to randomise participants according to the specifications above
- Secure and remotely accessible storage of specified data in forms that can easily be made into a CSV file
- Comprehensive capture of app usage data
- Integration with Healthkit (iOS8) and/or APIs developed by fitness, calorie and sleep tracking apps (such apps to be determined)
- Design for a single-page website with a maximum screen resolution of 1170px and that is responsive to handheld devices

User testing

Please allow for two rounds of user testing: one of the app's design before build commences; the second of the app before it is released. We will recruit users and manage the testing so no budget needs to be allocated for this purpose. However, your build schedule should allow for it to take place.

Intellectual property and copyright

All code for the app will be released under a 'GPL V3' open source licence. All copy will be released under a 'Creative Commons By' licence. The developer should ensure that any code used within the app, whether developed in-house or incorporated from other sources, is licensable on the same terms. If you propose using libraries that are not open source, please explain your rationale and how the app could still be released under an open source licence.

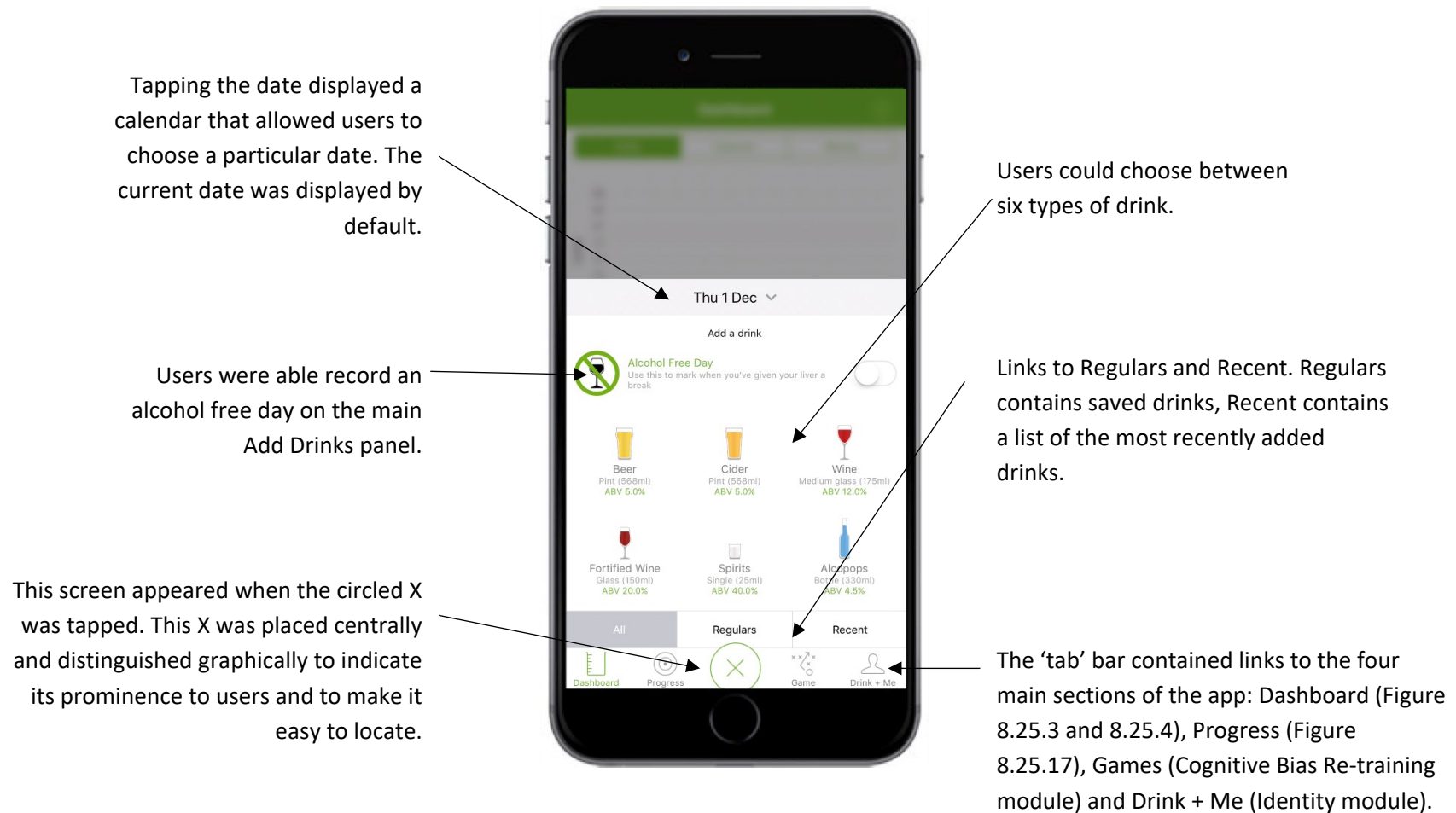
Next steps

Please provide your response to this brief with the approach you propose taking, detailed costings and a development timeline assuming a start date of August 18th. Examples of similar work should be supplied where possible, particularly when work relevant to mobile health has been completed.

Please also detail your day rates for each member of staff you expect would be involved in making changes to the app following its release. Include not just coders and designers/UX specialists but also any administrative staff (such as project managers).

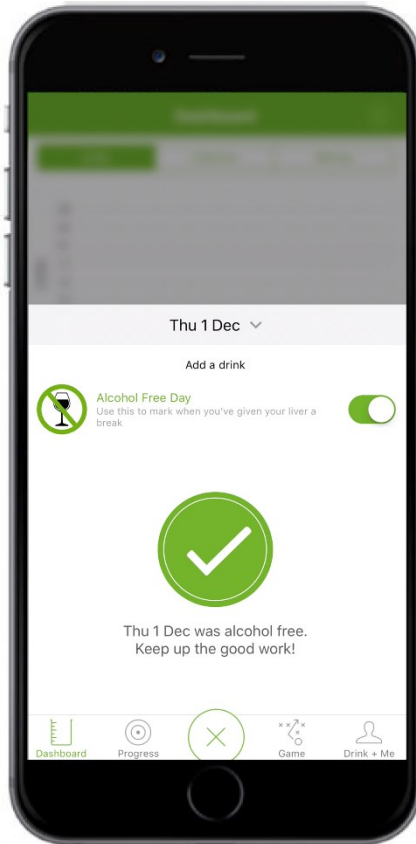
8.25 Screenshots – experimental conditions

8.25.1 Self-monitoring and Feedback: Add Drinks panel



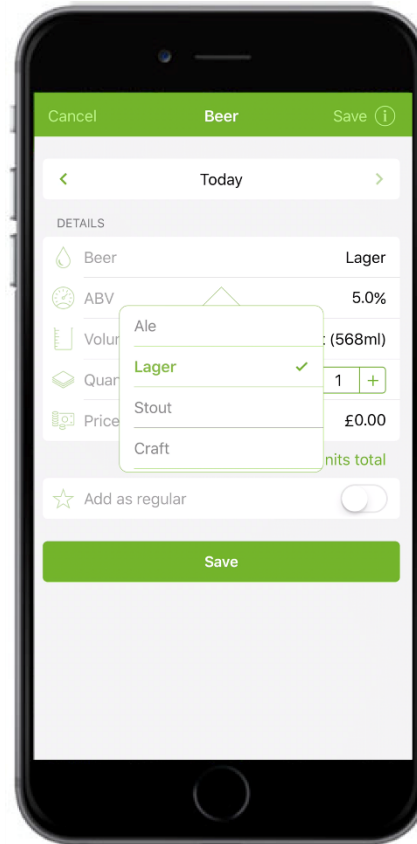
8.25.2 Self-monitoring and Feedback: Add Drinks – Alcohol Free Day, Drink Details and Info button

1



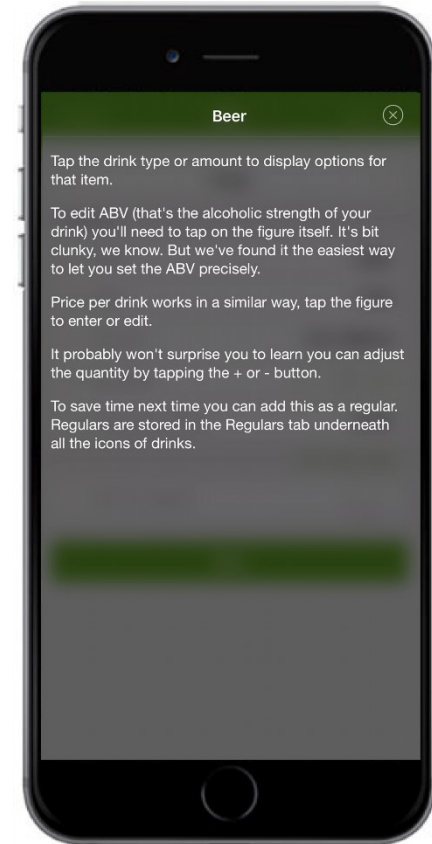
If a user marked a day as alcohol free a large green tick was displayed, a pleasing sound was played and text provided positive reinforcement

2



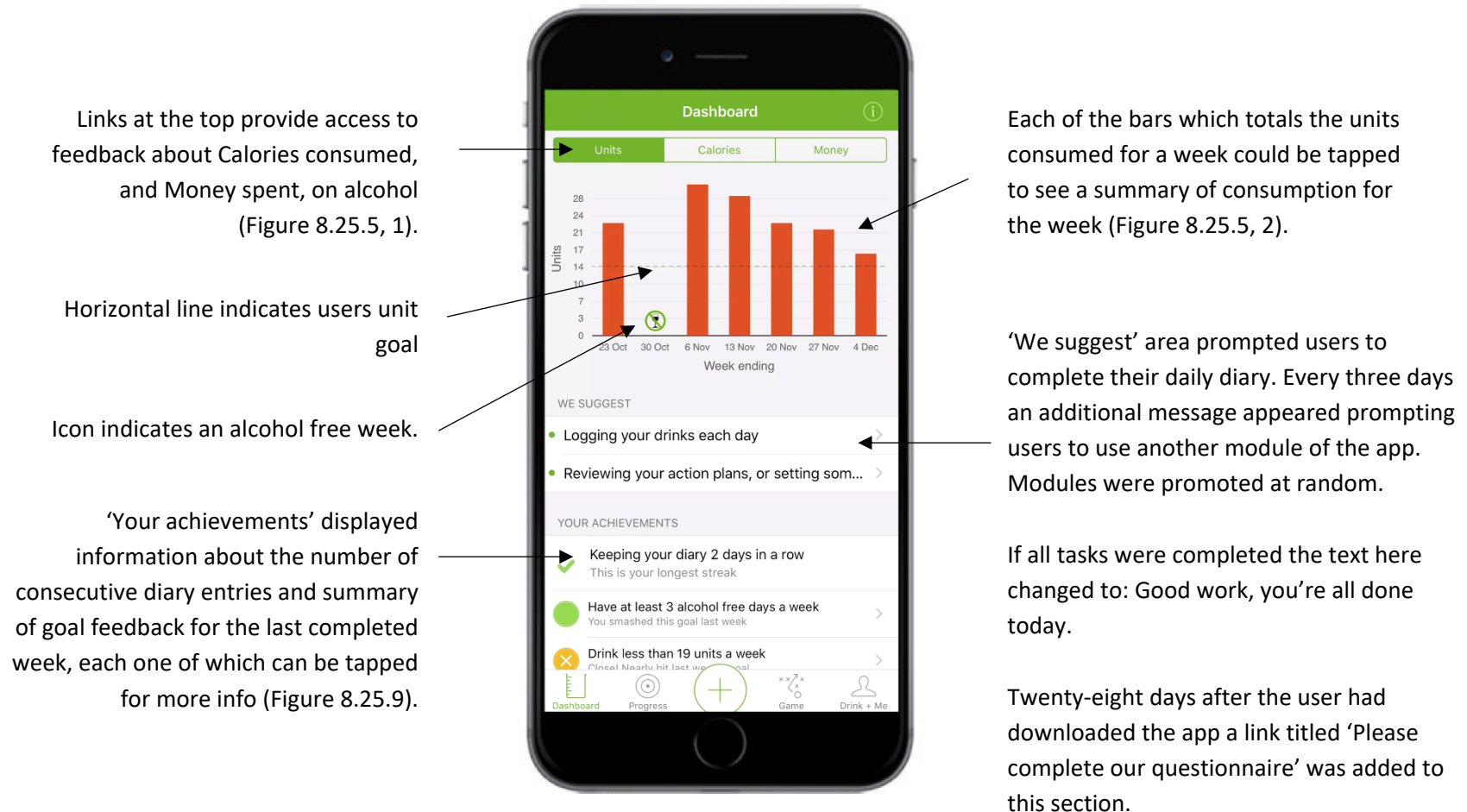
When a drink was chosen (beer in this case) the options for that drink were displayed. Users could also add the drink as a Regular

3



The information button (top right on the previous screen) helped participants understand how to enter data. Informal language was used

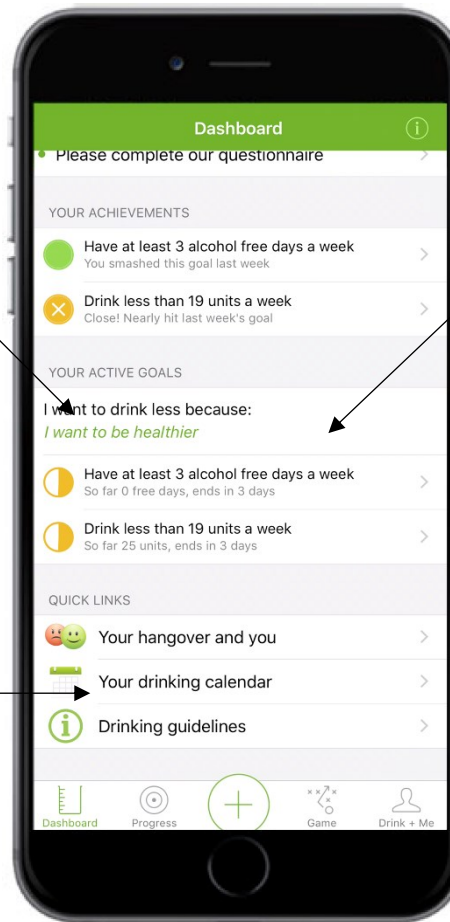
8.25.3 Self-monitoring and Feedback: Dashboard top



8.25.4 Self-monitoring and Feedback: Dashboard bottom

The green text under 'I want to drink less because:' displayed user entries to the first question asked in Goal setting (Figure 8.25.15, 1)

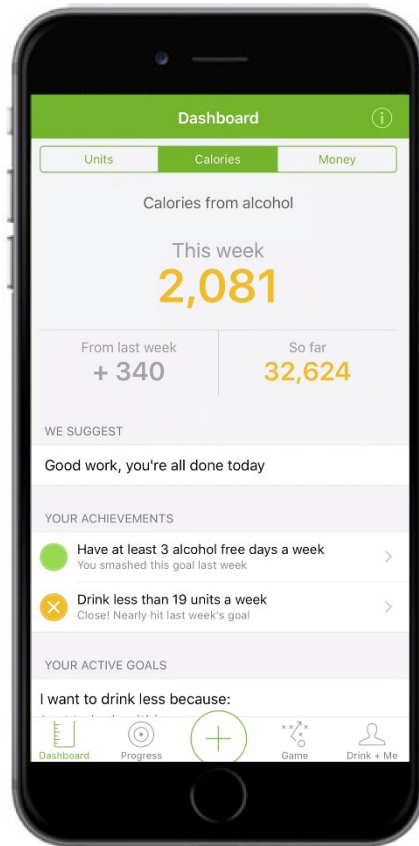
'Quick Links' provided one-tap links to Mood Diary feedback (Your hangover and you, Figure 8.25.8, 2), a user's drinking calendar (Figure 8.25.10, 1) and UK Government guidelines for alcohol consumption.



'Your active goals' also displayed information about progress toward goals for the current week. In the example here, the half-filled circle indicated the user was half-way through the current week, and the text below the goal title summarised how many alcohol free days they had had or units they had consumed to date.

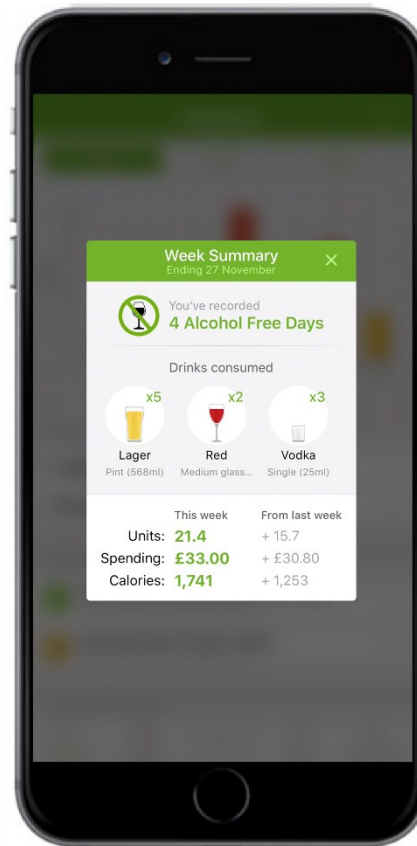
8.25.5 Self-monitoring and Feedback: Dashboard – Other graphs, Weekly summary and Info button

1



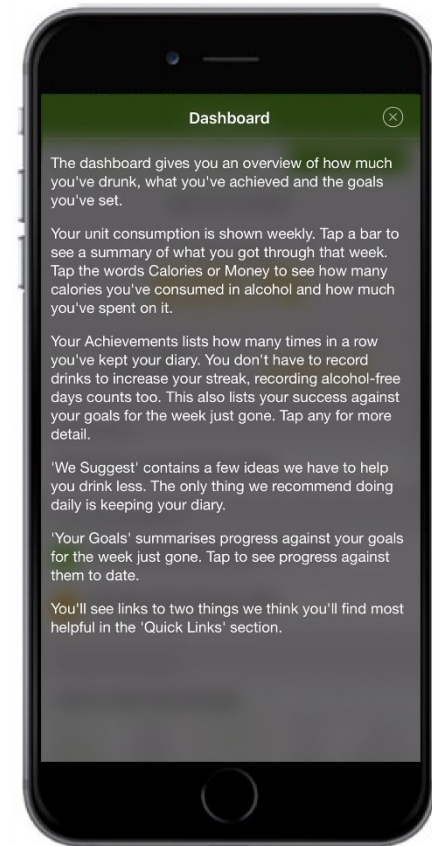
The Calories screen showed calories consumed from alcohol in the past week, to date, and how figures compared to the previous week

2



The weekly summary showed number of alcohol free days, totals of drinks consumed, and unit, spending and calorie totals and comparisons

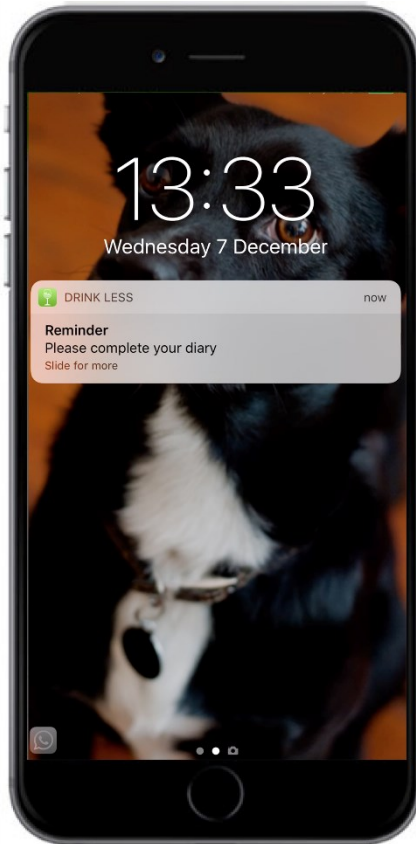
3



The info button (top right of the dashboard) provided further info about this screen. Text for controls differed (Figure 8.26)

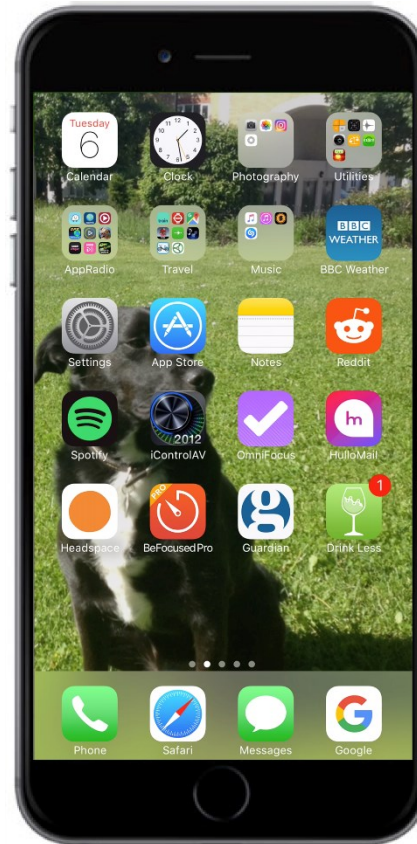
8.25.6 Self-monitoring and Feedback: Alerts to complete the drinking diary

1



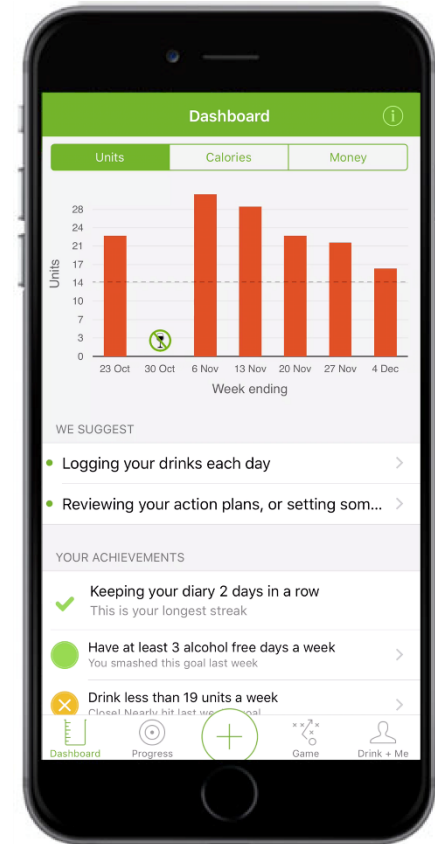
Prompt on the user's home screen

2



Alert on the 'badge app icon' (5th row, last app)

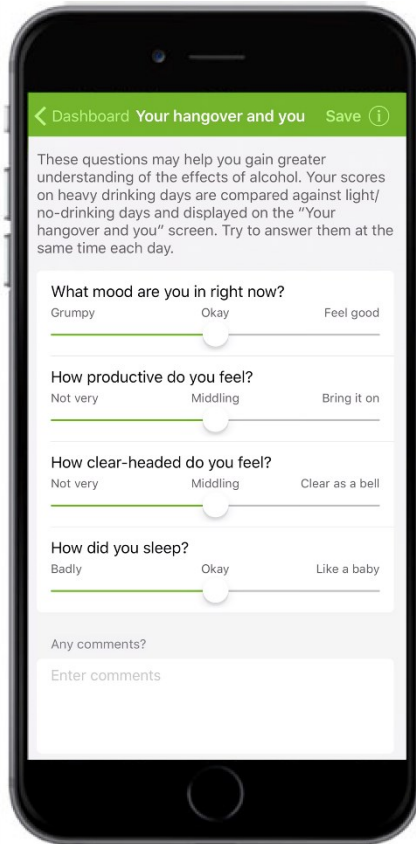
3



Alert on the Dashboard (In 'We Suggest')

8.25.7 Self-monitoring and Feedback: The Mood Diary questions

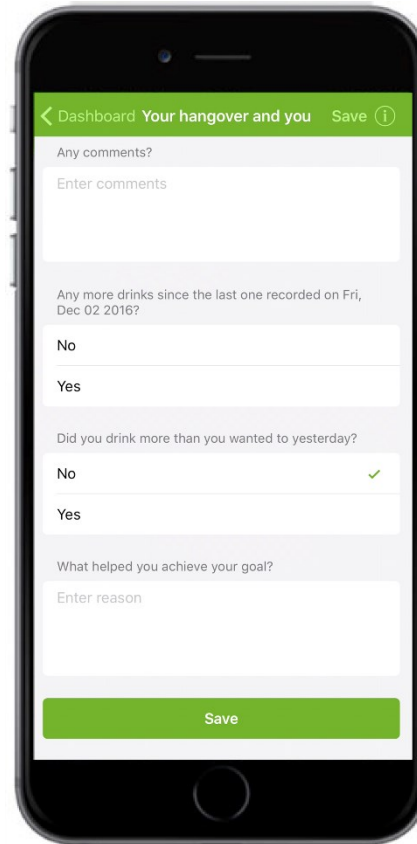
1



The screenshot shows a mobile app interface titled "Dashboard Your hangover and you" with a green header bar containing a back arrow, the title, a "Save" button, and an information icon. Below the header, there is a paragraph of text explaining the purpose of the questions. The main content area contains four horizontal sliders for mood and productivity, each with three labels: "Grumpy", "Okay", and "Feel good" for the first; "Not very", "Middling", and "Bring it on" for the second; "Not very", "Middling", and "Clear as a bell" for the third; and "Badly", "Okay", and "Like a baby" for the fourth. At the bottom, there is a section for "Any comments?" with a text input field labeled "Enter comments".

If users responded to the daily prompt to log their drinks they were presented with the Mood Diary questions, below which...

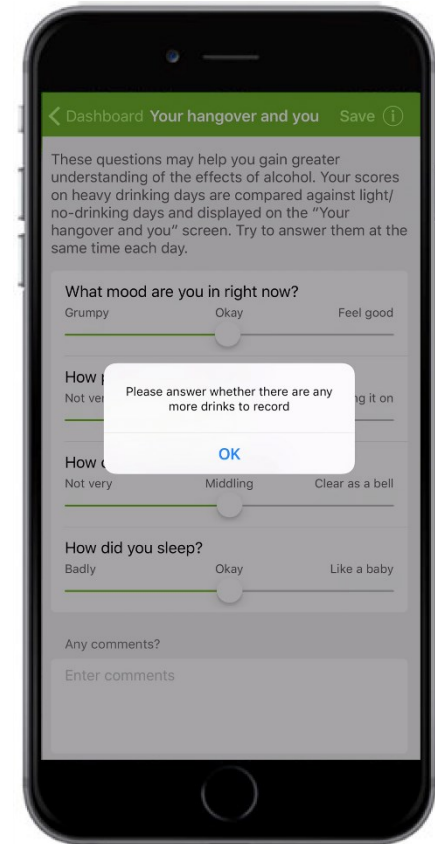
2



The screenshot shows the same mobile app interface as screenshot 1, but with additional questions. Below the "Any comments?" section, there is a question "Any more drinks since the last one recorded on Fri, Dec 02 2016?" with "No" and "Yes" radio button options. Below that is a question "Did you drink more than you wanted to yesterday?" with "No" and "Yes" radio button options, where the "No" option is selected and marked with a green checkmark. At the bottom, there is a question "What helped you achieve your goal?" with a text input field labeled "Enter reason" and a green "Save" button at the very bottom.

...were fields for comments, whether there were more drinks to record and whether the user drank more than they wanted to (Figure 8.25.8, 3)

3

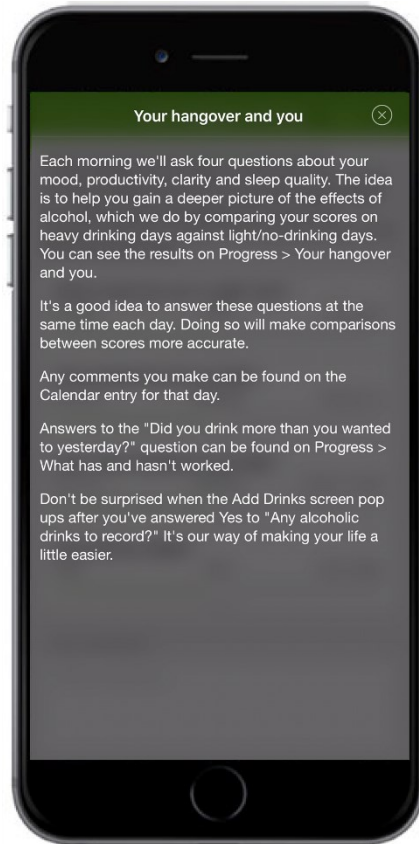


The screenshot shows the same mobile app interface as screenshot 1, but with a white alert dialog box overlaid in the center. The dialog box contains the text "Please answer whether there are any more drinks to record" and a blue "OK" button. The background of the app interface is dimmed.

If users did not complete all the required fields an alert informed them which field needed their attention

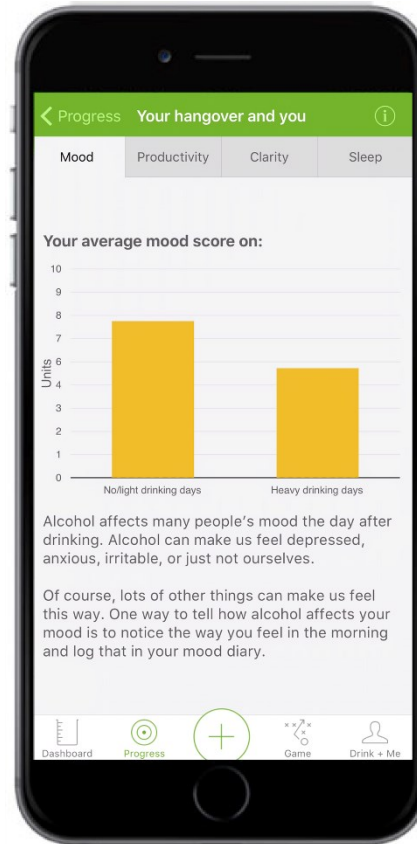
8.25.8 Self-monitoring and Feedback: The Mood Diary info button and Mood Diary feedback

1



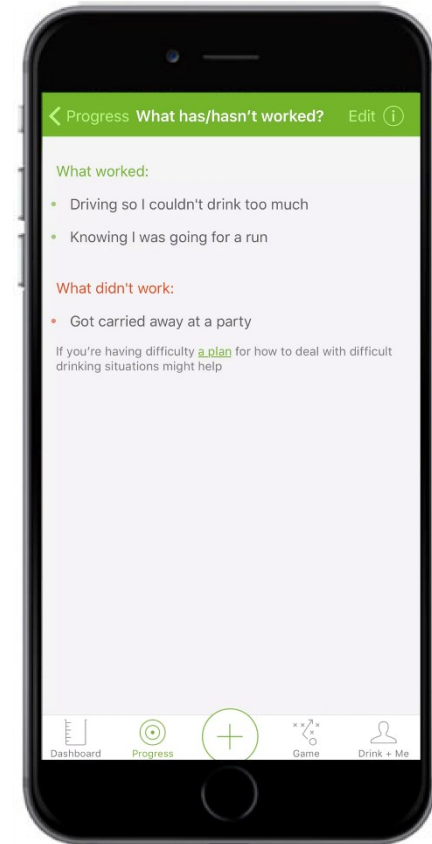
The info button explained the purpose of the Mood Diary and how to complete the form

2



Responses to the Mood Diary were displayed in 'Your Hangover and You', with text explaining why each measure might be affected by alcohol

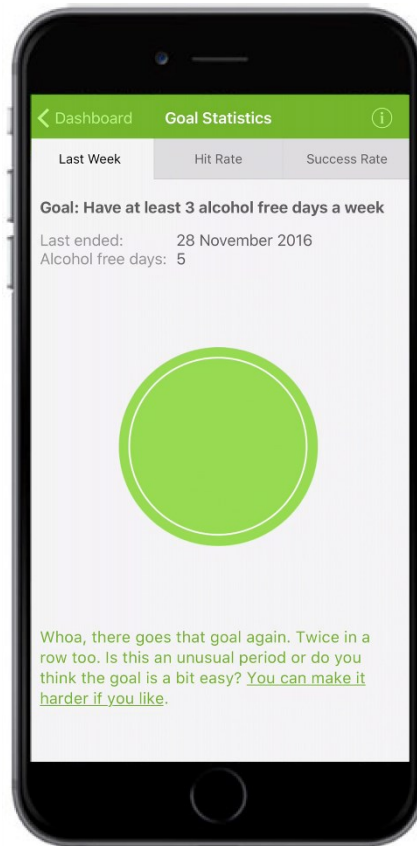
3



Responses to the 'Did you drink more than you wanted to yesterday?' were displayed on Progress > 'What has and hasn't worked'

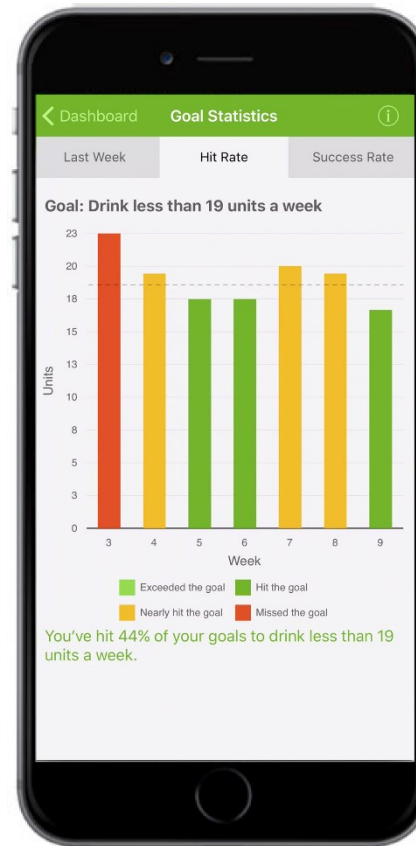
8.25.9 Self-monitoring and Feedback: Goal feedback

1



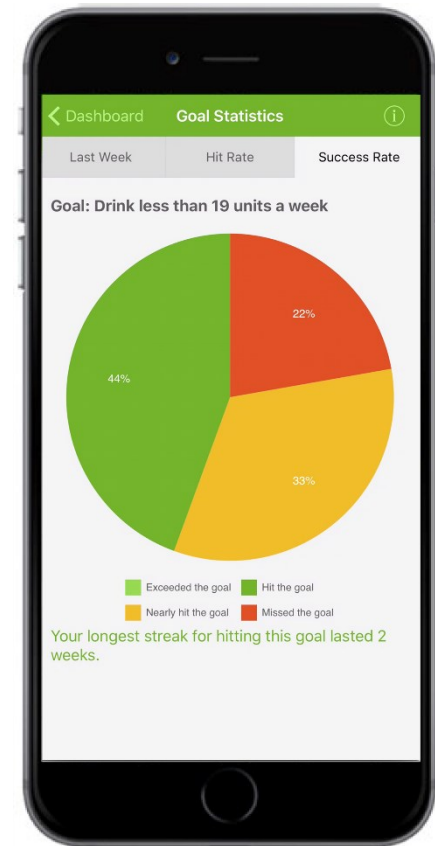
Info presented when summary goal feedback on the dashboard (Figure 8.25.4) or 'Set and view goals' screen (Figure 8.25.15, 2) was tapped

2



The goal 'Hit Rate' screen provided an overview of how many times the goal had been exceeded, hit or missed since the app was downloaded

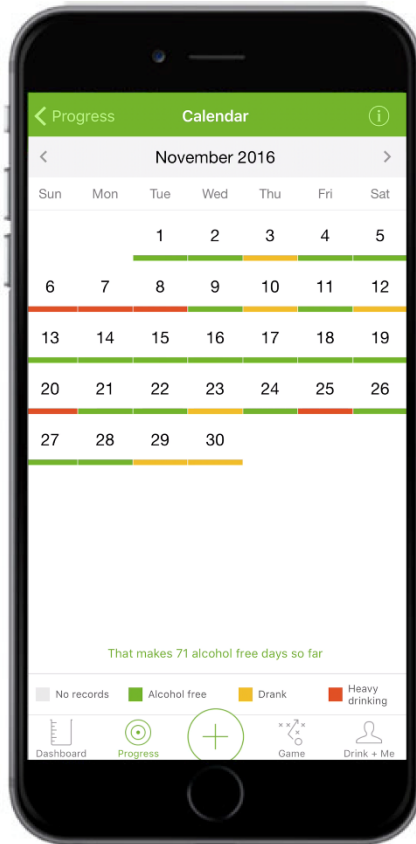
3



The goal 'Success Rate' screen provided a total of how many times the goal had been exceeded, hit or missed since the app was downloaded

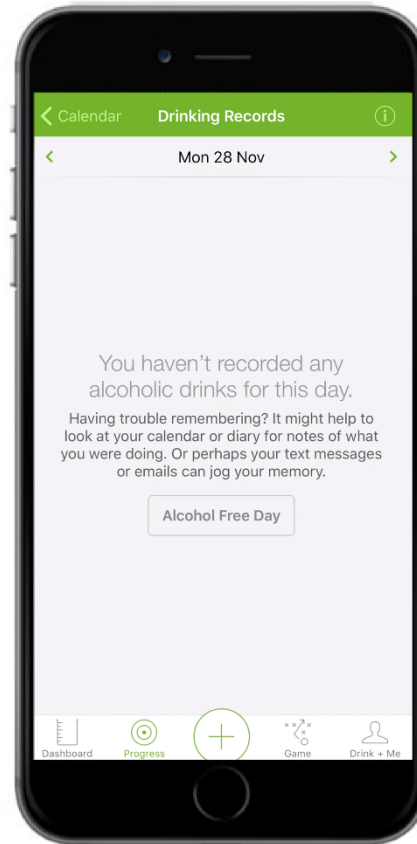
8.25.10 Self-monitoring and Feedback: Calendar

1



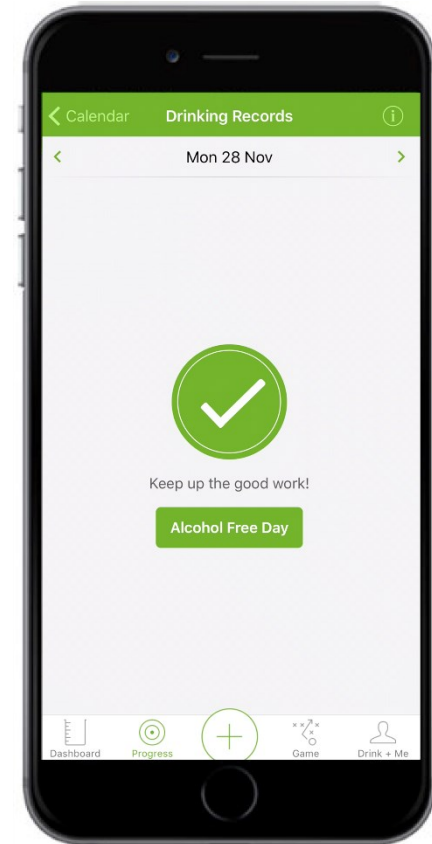
Coloured lines provided consumption feedback. Total number of alcohol free days was displayed toward the bottom of this screen

2



Timeline Followback procedure used to prompt people to recall past drinking behaviour. One touch button recorded an alcohol free day

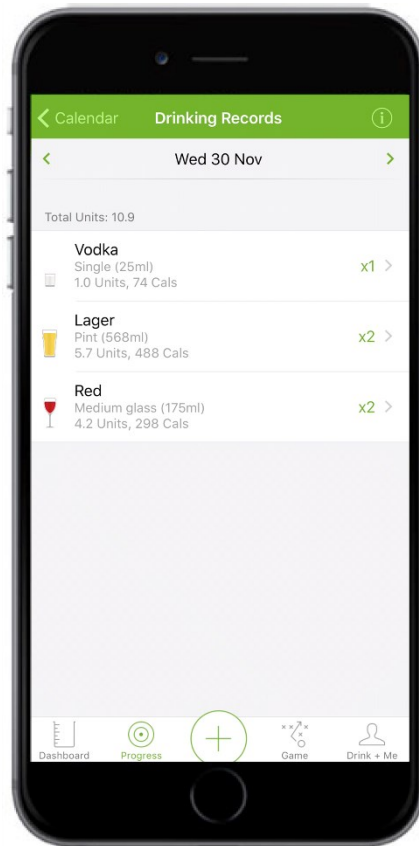
3



If an alcohol free day was recorded a big tick was displayed alongside the text 'Keep up the good work' and a pleasing sound was played

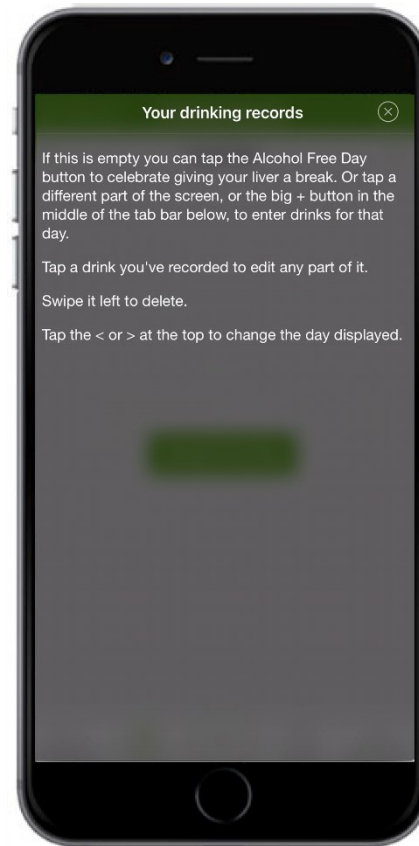
8.25.11 Self-monitoring and Feedback: Calendar – Individual days

1



Tapping a day on the calendar displayed the total units consumed and details of each drink. These drinks could be edited or deleted

2



Text displayed when the info button was pressed helped users understand how to use this screen, for example how to edit and delete drinks

8.25.12

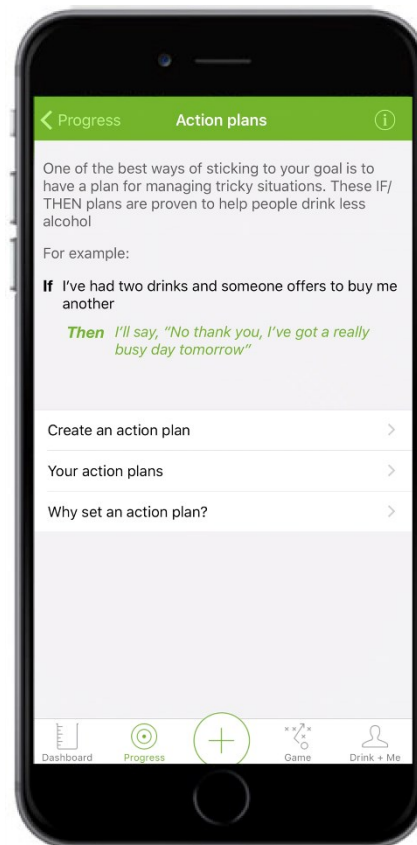
Action Plans – Main screen and Why set an action plan

1



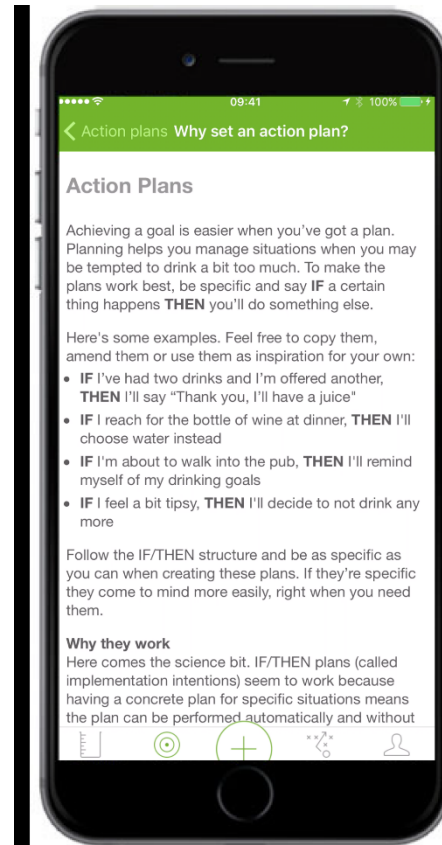
Action plans were accessed by tapping the top right icon on the Progress screen

2



The first Action Planning screen contained brief info about action plans, an example of an action plan and links to other screens

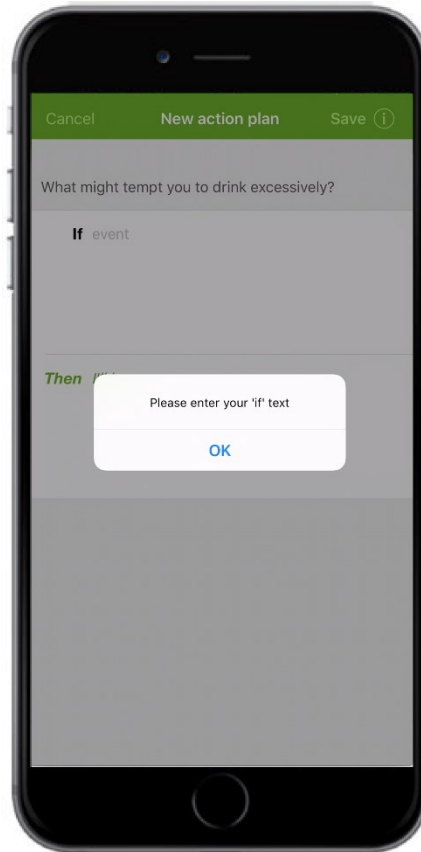
3



Information encouraging users to set an action plan and instructions about how they should be set was provided

8.25.13 Action Plans – Create an action plan

1



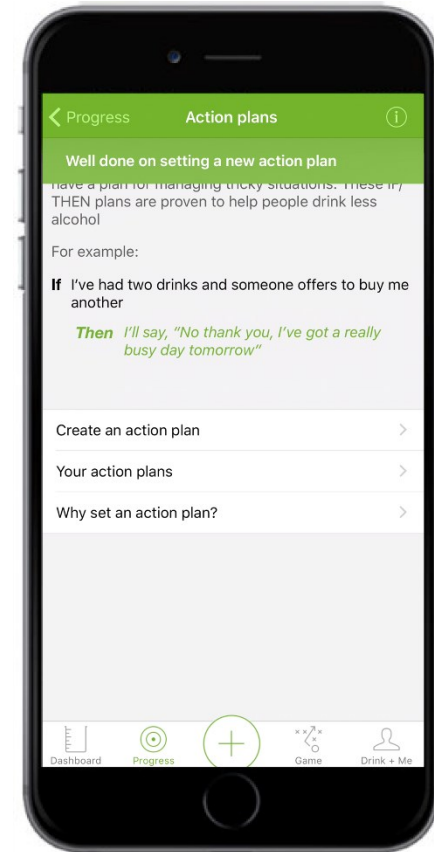
The “Create an action plan” screen contained separate fields for the If and Then components. An error message notified users of an empty field

2



Examples of Action Plans were provided. These were accessed via the info button on the ‘Create an action plan’ screen

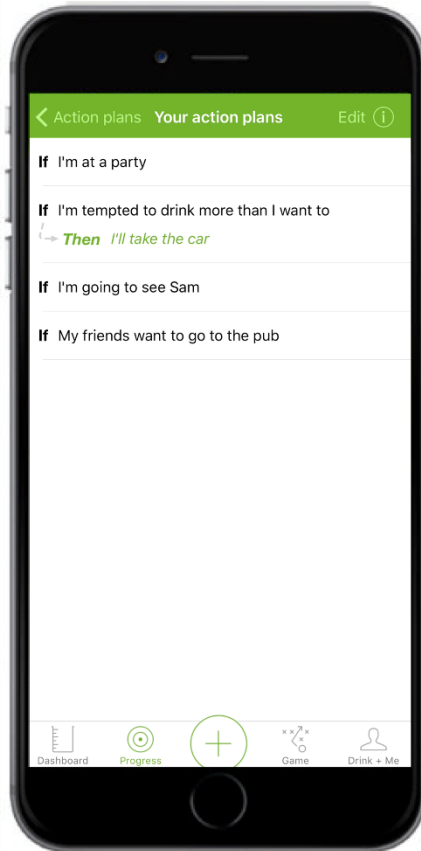
3



Once an action plan had been set a confirmation message appeared at the top of the screen. A pleasing sound was also played

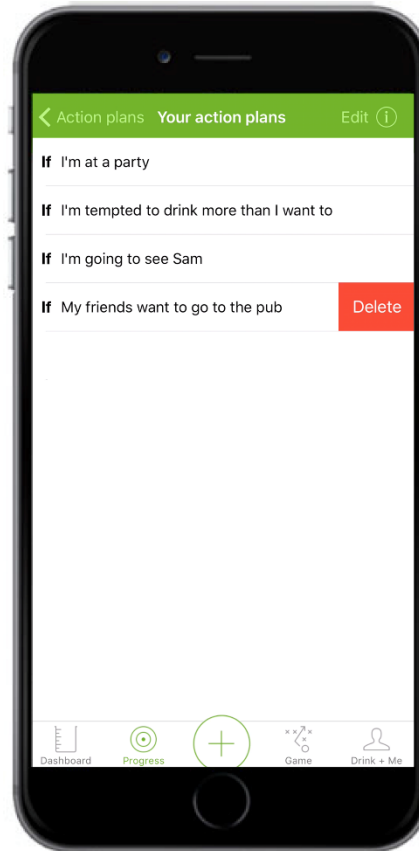
8.25.14 Action Plans – Your action plans

1



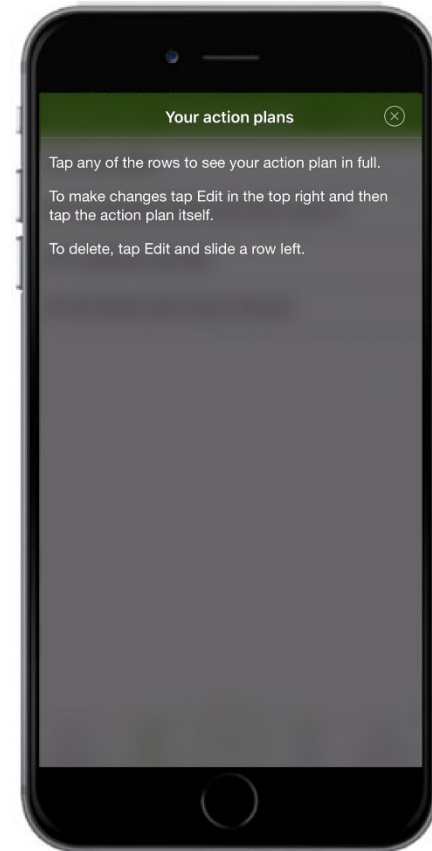
'Your action plans' contains a list of all the action plans a user has set

2



Any action plan can be edited by tapping it, or deleted by swiping left.

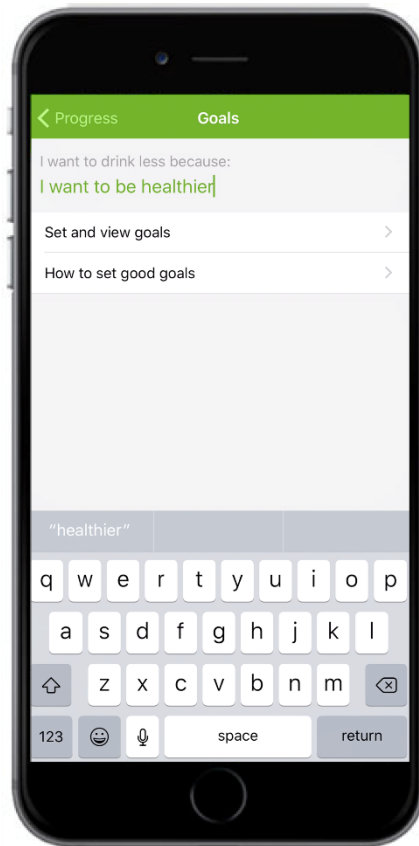
3



If the info button in the top right of 'Your action plans' was tapped, tips appeared to explain how action plans could be viewed, edited or deleted

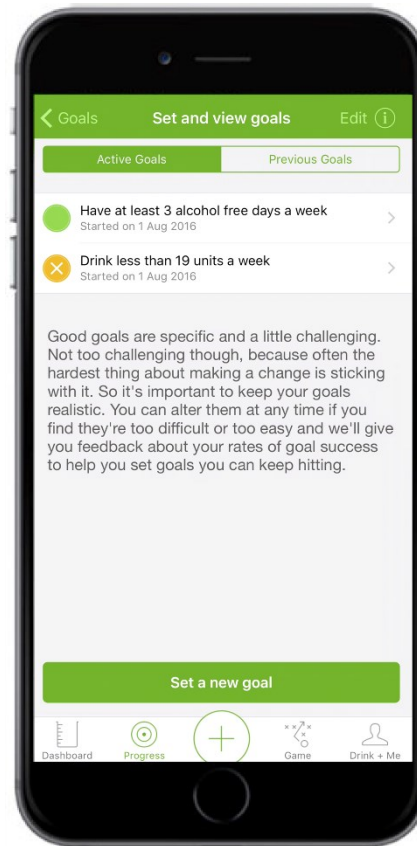
8.25.15 Goal setting

1



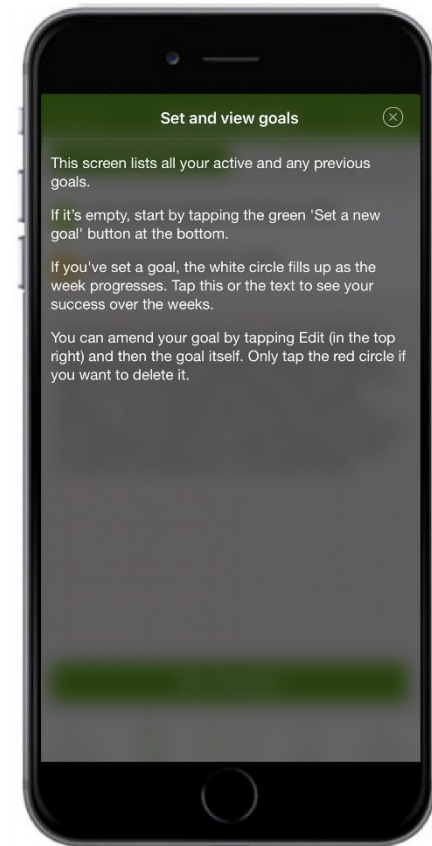
Users could set goals, get info on how to set good goals, and set an overarching goal for drinking less (displayed on the dashboard, Figure 8.25.4),

2



'Set and view goals' allowed users to set new goals and see summary feedback about current goals (Figure 8.25.9)

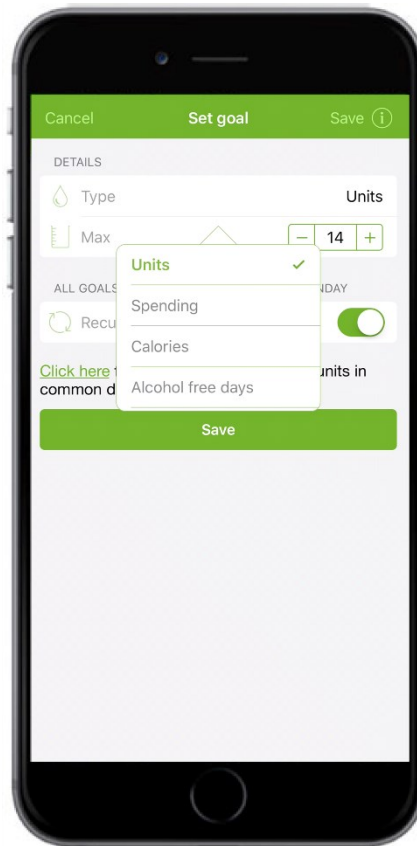
3



The Set and view goals info button provided more information about how new goals could be created or existing ones edited

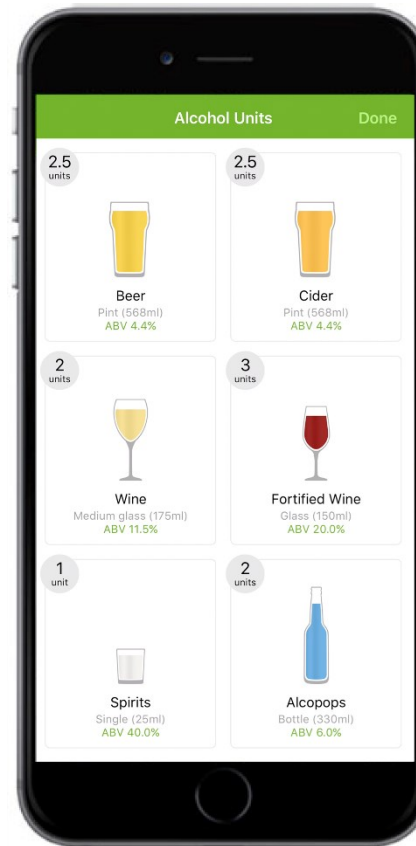
8.25.16 Goal setting

1



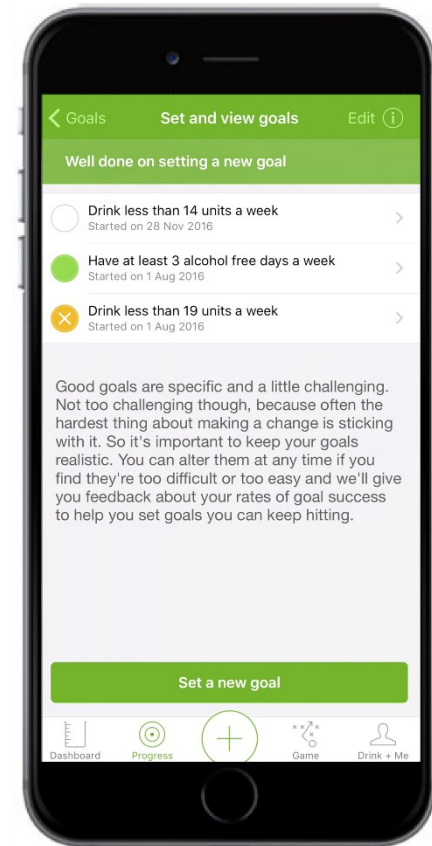
Setting a goal involved two steps: 1) choose a type of goal; 2) Set the target. A goal recurred by default, this could be turned off

2



If a Units goal was selected a link provided users with a guide about the number of units in typical drinks

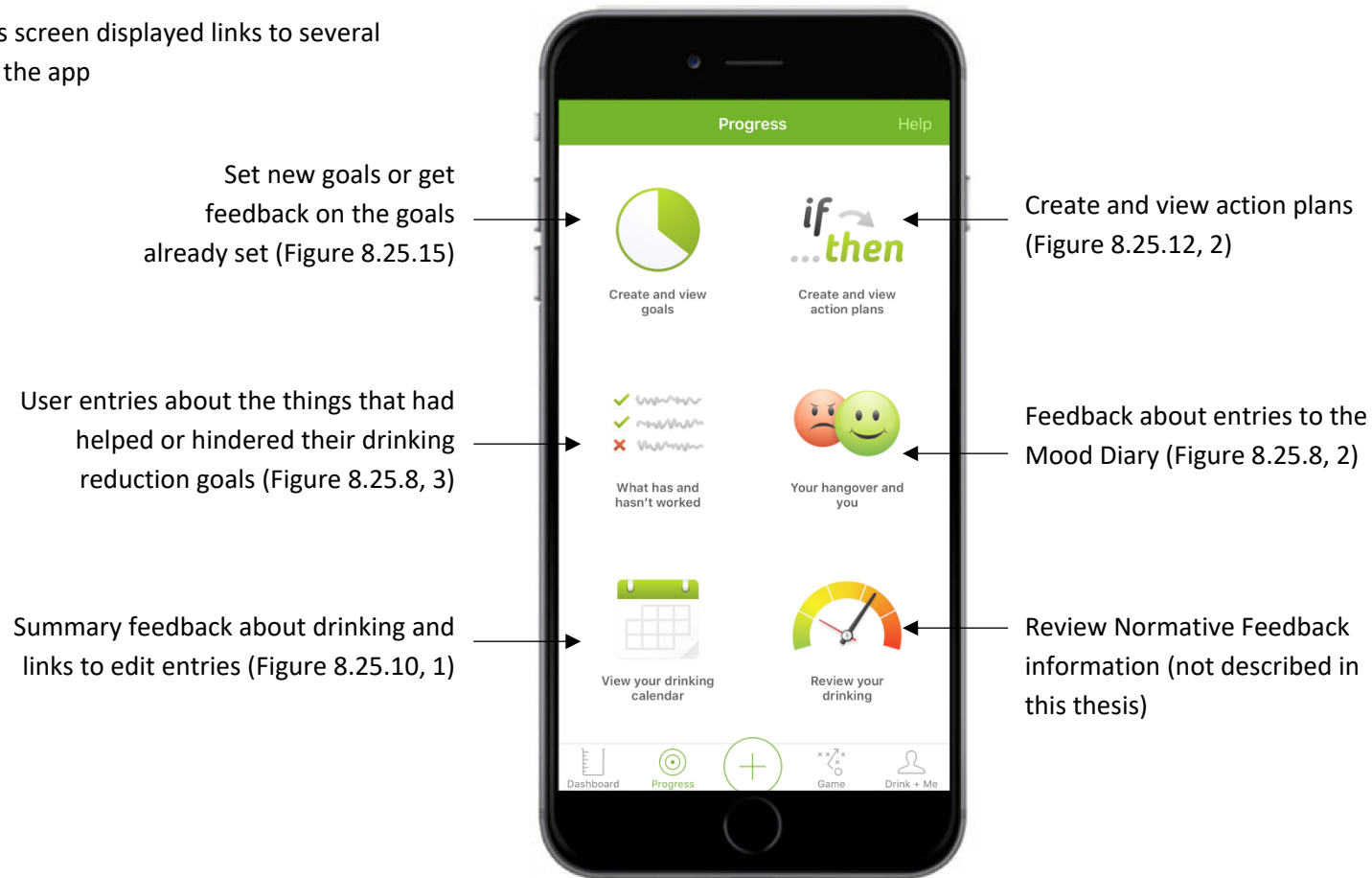
3



A congratulatory message appeared (top of screen) and pleasing sound was played when a goal had been successfully set

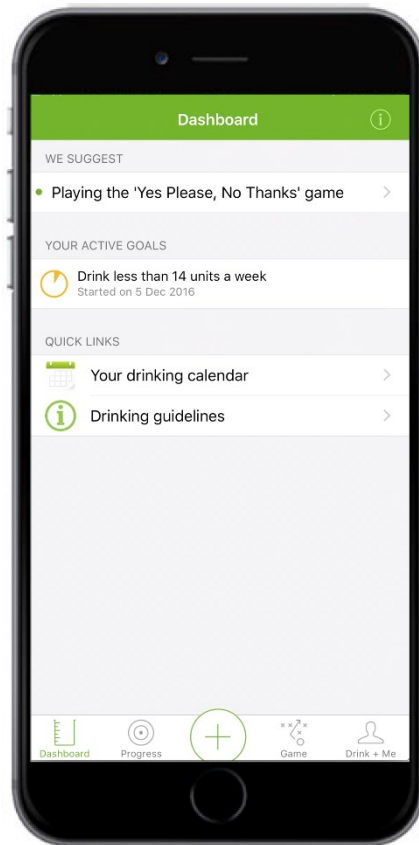
8.25.17 Progress screen

The Progress screen displayed links to several elements of the app



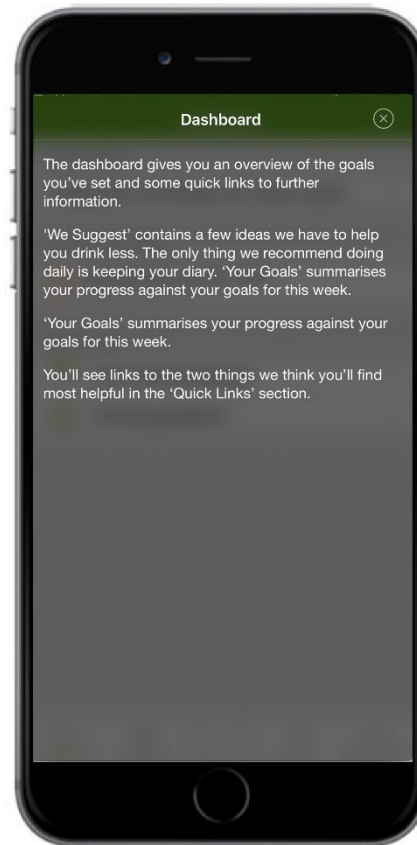
8.26 Screenshots – Self-monitoring and Feedback control

1



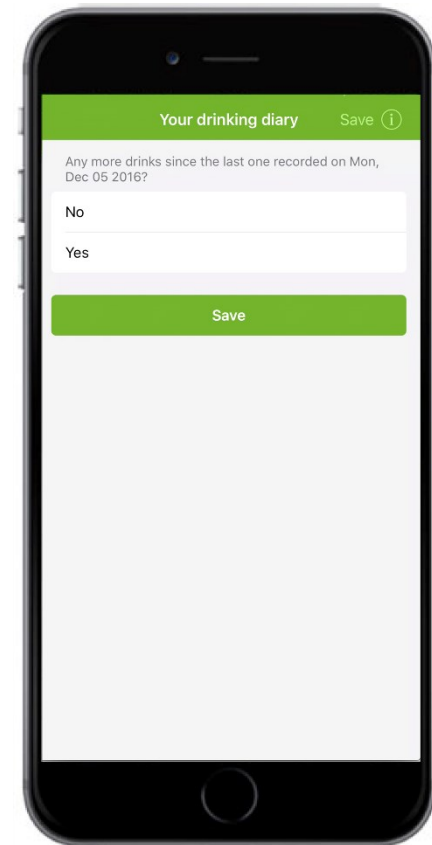
Control participants were given a plain dashboard with no graphs and no feedback. 'Your active goals' simply reminded users of their goal

2



The text displayed when the information button was pressed related to the screen that control participants saw (diff to Figure 8.25.5, 3)

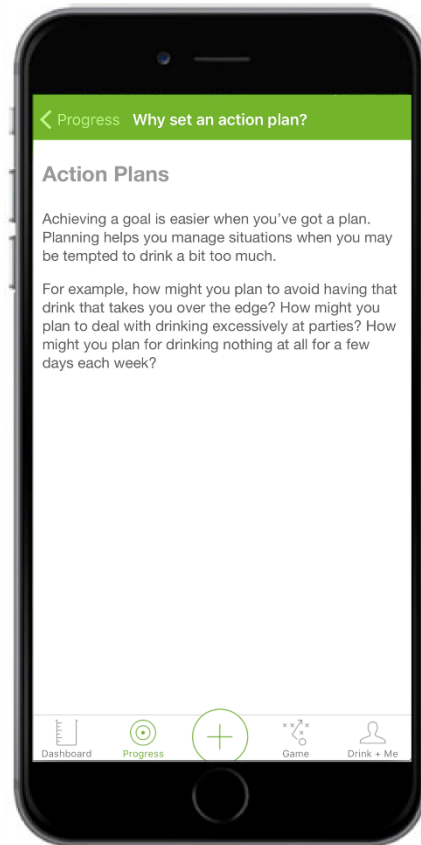
3



If users responded to the prompt to complete their daily diary they were only asked if they had drinks to record, no Mood Diary questions asked

8.27 Screenshots – Action Planning control

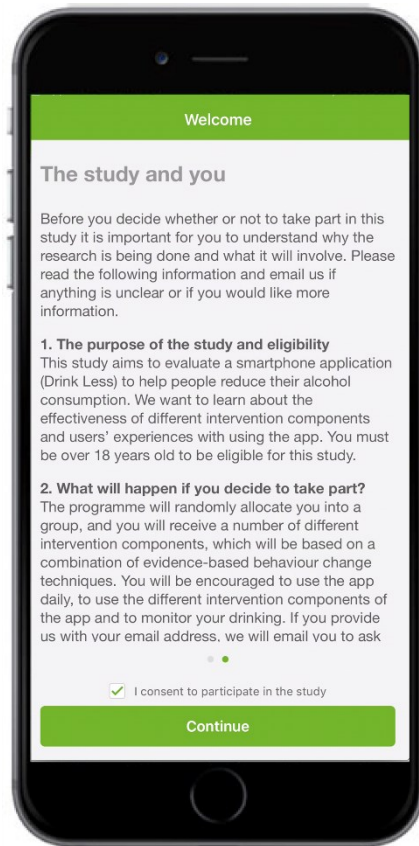
1



Control participants who tapped Create and View Action Plans (fig 8.25.17) were given only brief details about action plans

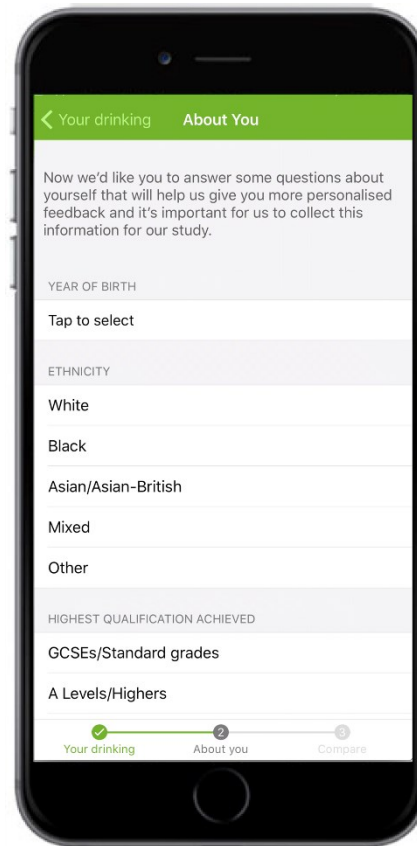
8.28 Screenshots – Registration part 1

1



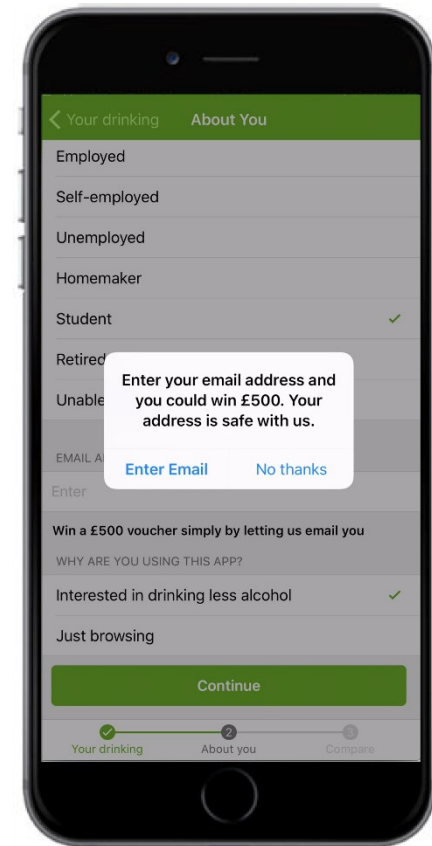
The information to consent screen provided details about the study. Users needed to consent to participate to be able to use the app

2



Text at the top of baseline questionnaires explained why the info was needed. An indicator at the bottom showed how many steps to go

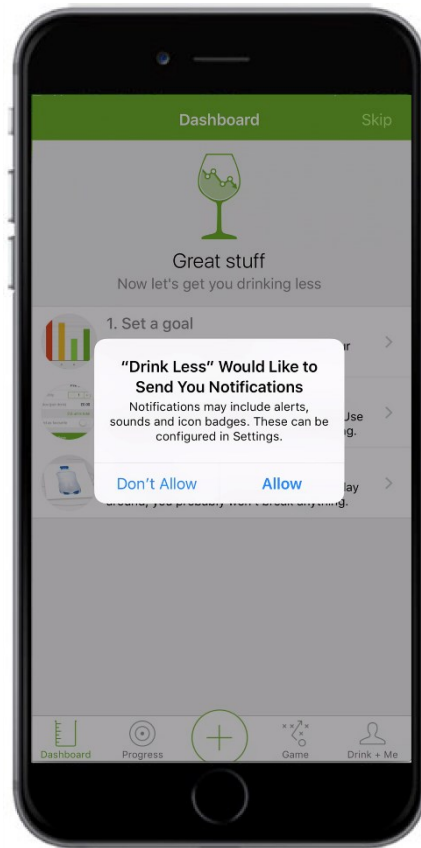
3



Users were prompted to complete the email field if they originally left it blank. Choosing No Thanks allowed users to continue

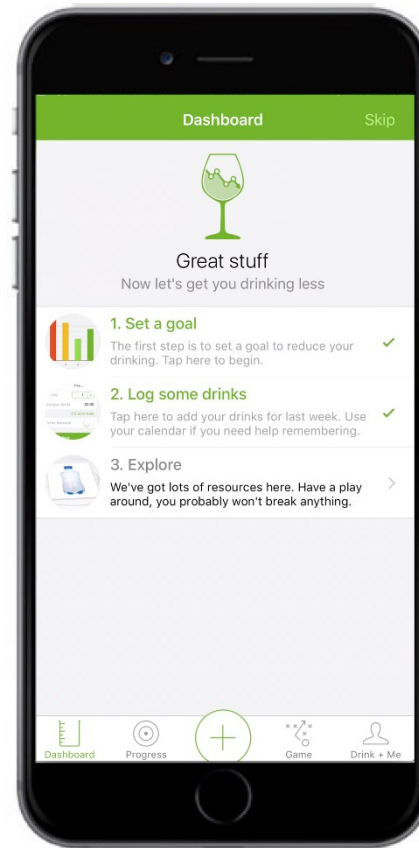
8.29 Screenshots – Registration part 2

1



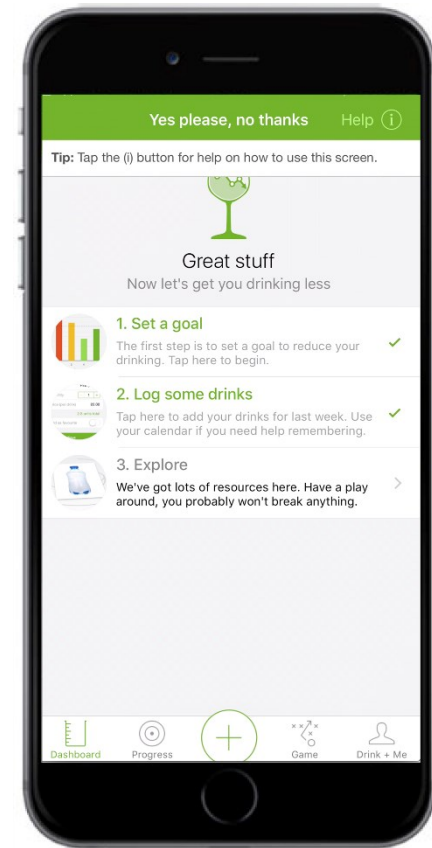
Users were asked to consent to notifications only when they were some way into using the app. Seeking permissions too early can dissuade users

2



The stepped guide gave users three tasks to familiarise themselves with the app. Completed steps were greyed-out and ticked.

3



The info button (top right) provided useful information about using the app. A message at the top brought its existence to user's attention

8.30 Apple App Store listing

App Store > Health & Fitness > Susan Michie



Download

★★★★☆ (7)

Rating: 17+

LINKS

Privacy Policy

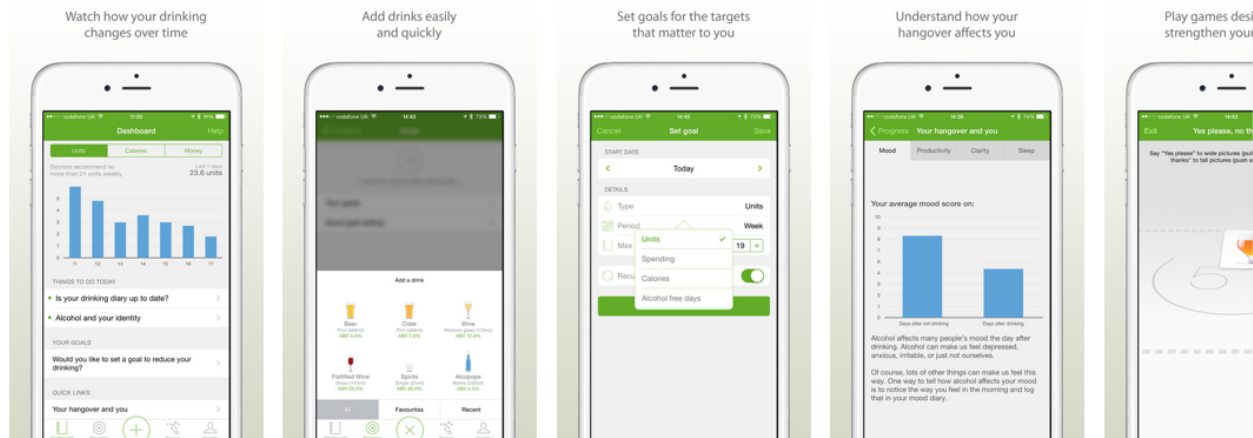
© Susan Michie 2015

Drink Less: help reducing your alcohol consumption 17+

Susan Michie >

Details Ratings and Reviews Related

iPhone Screenshots



Description

Are you looking to cut down how much you drink? If so, we can help. Drink Less is a super-easy to use app that allows you to keep track of how much you drink, set goals to drink less, get feedback on whether what you're doing is working and access some unique and fun ways of changing your attitude towards alcohol.

You can:

- Keep track of your drinking and see how it changes over time
- Set goals for the targets that matter to you and get feedback on your progress towards them
- Complete a daily mood diary so you can better understand the effects of your hangover
- Play games designed to strengthen your resolve to drink less alcohol
- Create plans for dealing with situations when you may be tempted to drink excessively
- Take part in exercises designed to change your relationship with alcohol

Drink Less has been created by a team of psychologists at University College London; we're researching what techniques help people reduce their consumption of alcohol. You can use the app fully without taking part in our study and you can opt-out of it at any time. But if you do participate you'll be helping us understand how to help more people drink less. And both we, and science, will be very grateful.

This app is for people aged 18 or over.

Text informs
potential users
that the app is part
of an experiment



8.31 Open source licences for *Drink Less* - BSD 3-Clause License

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8.32 Code repository for *Drink Less*

All code for *Drink Less* can be accessed from the following repository:

<https://github.com/UCL-Centre-for-Behaviour-Change/DrinkLess>

All code is released under a BSD 3-Clause License (Appendix 8.31)

8.33 Using the app as a platform

As noted in Chapter 7, there are considerable benefits to using an existing app as a platform for further research. In brief, these are that iterative changes to an existing app can allow for more accurate determination of the mechanisms of an action of an intervention. Such changes will usually be cheaper, and can be completed more quickly, than building an entirely new app. Changes found effective could be retained within the app and made available to the public.

Moderately popular apps, such as *Drink Less*, can receive the number of downloads that would make multiple annual trials possible. However, conducting and reporting multiple annual trials is likely to exceed the resources of a single research team. Alternatively, it may be possible for different research teams to conduct trials on the same app. Such an approach would present organisational, procedural and technical challenges. This document outlines a method for how these challenges may be overcome.

8.33.1 An overview of the process

An existing app, *Drink Less* for example, would be made available to other researchers who wish to evaluate the effectiveness of different BCTs, different combinations of BCTs, or different implementations of BCTs. Research proposals would outline what changes were to be made, why those changes were theorised to work and why they are important to evaluate.

A simplified example schedule can be found on Figure 8.33.1. This assumes a rate of download of 1,200 people a month, a third of whom would consent to participate in the study (which reflects *Drink Less* numbers). If the sample size was 700, recruitment could be completed in two months. Follow-ups would be fixed at one-month for reasons of scheduling. Each trial could contain a number of changes that would be evaluated in a

factorial RCT. A new version of the app with changes made for Trial 2 would be released once recruitment for Trial 1 had finished. Participants in Trial 1 would not have access to this version – or any other updated version – until follow-up was complete.

For example, if Trial 1 started on 1st January it would complete recruitment by 1st March. Follow-up would start on 1st April and analysis on 1st May. Recruitment for Trial 2 would start after recruitment for Trial 1 on 1st March. Participants from Trial 1 would not have access to updated versions of the app until follow-up is complete, i.e. from 1st May (Figure 8.33.1).

8.33.2 Organisational challenges: The Scientific Committee

A Scientific Committee, consisting of domain and app development experts, would oversee the selection and scheduling of trials. It will be important not just to prioritise proposals that address pressing research questions, but also to ensure that changes to the app are technically feasible. Decisions could be made online and may be required no more than biannually.

Once a research proposal has been chosen a member of the Scientific Committee will need to liaise between the research and development team before and throughout the trial. Their role would be to oversee the process of implementing changes into the app and helping resolve issues that arise. This may involve making sure that the development team understands the research objective(s) and what changes to the app need to be made; helping the research team address problems with implementing these changes; resolving technical issues during testing or once the trial commences; and ensuring that the research team have the data they need to analyse. It is unlikely that these steps could be completed effectively by the researchers themselves, not least because developers may not know who to prioritise if multiple research teams were requesting them to do work.

8.33.3 Procedural challenges

App development will not always run to schedule. It can take longer than anticipated to make changes and resolve implementation issues. A schedule flexible enough to accommodate delays could be achieved if multiple proposals are approved by the Scientific Committee and worked on by the development team at the same time; in this way, should Trial 2 not be ready, Trial 3 could start in its place.

8.33.4 Technical challenges

To maintain the integrity of each trial it will be necessary to ensure that participants do not have access to any changes made for a subsequent trial. The timeline in Figure 8.33.1 shows that at least two versions of the app will be available at any one time; for example, when Trial 2 is launched the app will contain the changed code for that trial (v1.2) as well as unchanged code for the continuing Trial 1 (v1.1).

This timeline could present considerable technical challenges because, on iOS at least, the operating system requires certain files be present and does not allow files to be stored in directories. This means that duplicate files may need to be created and renamed, which could create a file system that is highly complex to manage.

It is uncertain at this point whether the file system would be too complex to manage or if this issue could be addressed with detailed documentation, rigorous development, and thorough testing. If this isn't effective, or if alternative file management solutions cannot be found, it may be necessary to alter the timeline such that the version of the app for Trial 2 is not released until follow-up is complete for Trial 1.

8.33.5 App web site

A dedicated website for the app could contain details and results of all previous trials; details of upcoming trials, their hypotheses, and the changes to the app that will result; and regularly updated details of user characteristics. All of which may be useful for researchers preparing a research proposal, or researchers more generally. In addition, old datasets could be made available for verification of analyses.

In time, findings on this website could be directly peer reviewed by readers. Website users are expected to include domain experts whose review activity could perhaps be taken in consideration when determining which research proposals to approve. 'Publishing' findings in this way would be unusual. However, media such as music, books, journalism and film are tending towards forms of publishing that focus on a particular subject area or are aimed at a particular audience, and an app 'journal' on a website could be a logical extension to the number of specialised electronic journals that already exist.

8.33.6 Funding

This proposal requires a considerable amount of ongoing work, partly from the Scientific Committee but especially from the person or persons who act as liaison between the researchers and developers. Funding to cover expenses and any paid positions may need to be secured.

8.33.7 Other opportunities for researchers

In addition to conducting trials on the app, researchers could also use the app to recruit participants for studies conducted external to it. People who download a behaviour change app and volunteer to take part in one study may be interested in participating in others. A

population of self-directed treatment seekers from different countries, of different ages and with different backgrounds may be of interest to qualitative or quantitative researchers.

8.33.8 An Iterated proposal

It is reasonable to expect that some of the solutions proposed here will prove unworkable in practice. It is also likely that some parts of the process have been overlooked. Therefore, this is intended to be a draft proposal, one which should itself be regularly tested and improved.

Figure 8.33.1 – Example schedule

